THE UNIVERSITY OF ALBERTA

MICROPALEONTOLOGY OF THE BEARPAW FORMATION
SOUTHWESTERN ALBERTA FOOTHILLS

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Micropaleontology of the Bearpaw Formation, southwestern Alberta Foothills", submitted by R.K. Rosene, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Seventeen species belonging to eight genera of arenaceous foraminifera, nine species belonging to eight genera of calcareous foraminifera, two types of diatoms, one species of radiolaria (*Dictyomitra*), and ten species of ostracodes, belonging to five genera, are figured and described from the Late Cretaceous Bearpaw Formation of the southwestern Foothills of Alberta. The foraminiferal assemblage contains *Saccammina* (5 species), *Reophax* (1), *Miliammina* (1), *Haplophragmoides* (5), *Trochammina* (1), *Verneuilinoides* (1), *Gaudryina* (1), *Dorothia* (1), *Quinqueloculina* (1), *Dentalina* (1), *Neobulimina* (1), *Praebulimina* (1), *Eoeponidella* (2), *Serovaina* (1), *Heterohelix* (1), and *Gavelinella* (1). The ostracode assemblage contains *Reconcavona* (2 species), *Cypridea* (2), *Pontocypris* (1), *Haplocytheridea* (3), and *Veenia* (2).

The lower forty feet of the Bearpaw Formation carries an ostracode assemblage; 40 to 395 feet above the base of the Bearpaw Formation there is an arenaceous foraminiferal assemblage; and the fauna above 395 feet above the base carries the *Gavelinella talaria* assemblage.

The sediments were deposited in shallow water and four ecologic realms are identified. The sediments represent the deposits of a single transgressive-regressive cycle.

Both the upper and lower boundaries of the Bearpaw Formation are diachronous. The Lundbreck section correlates with a part of the *Anomalinoides* sp. Zone of North and Caldwell (1970), and with a part of the *Eoeponidella strombodes* and *Cassidella tegulata* -

Marginulina cf. *dorsata* Zones of Given and Wall (1971). The Bearpaw Formation of the southwestern Foothills of Alberta is restricted to the *Baculites cuneatus* Zone and the lower part of the *Baculites reesidei* Zone.

Microfaunal comparisons suggest a connection of the sea from southwestern Alberta to Alaska during the Late Campanian time.

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L.S. Eliuk assisted Dr. Wall in the collection of the outcrop material and R. Anan-Yorke processed certain selected samples.

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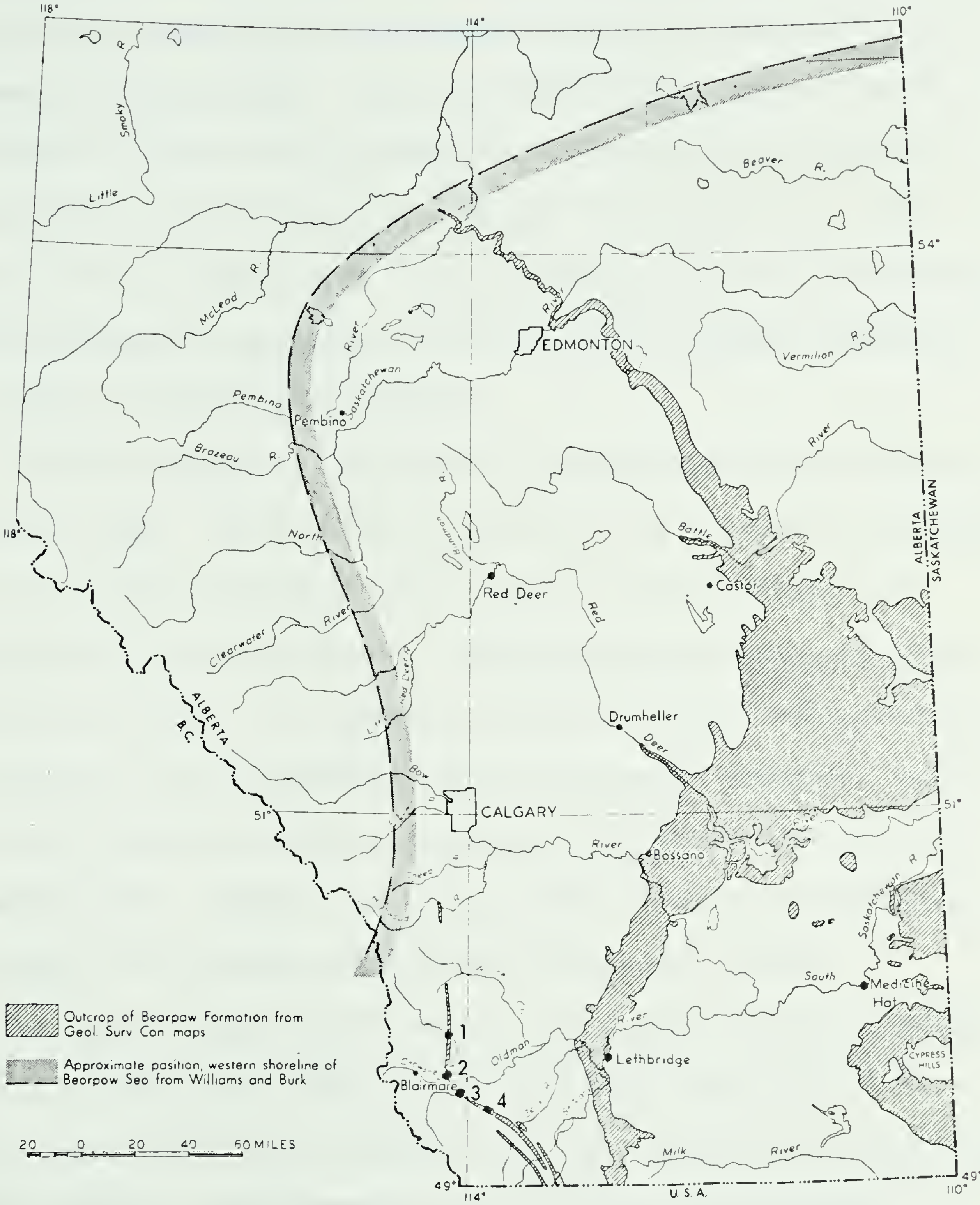
CHAPTER ONE

INTRODUCTION

This thesis is concerned with a varied microfossil assemblage from the Cretaceous Bearpaw Formation of the southwestern Foothills of Alberta. The Bearpaw Formation in this locality is almost completely exposed and occupies a position relatively near the inferred western margin of the Bearpaw sea. This gives it an importance in paleogeographic studies as most of the previous work on the Bearpaw fauna has been concerned with the more offshore facies to the east in central Alberta and Saskatchewan.

Western Canada experienced periodic marine floodings dating back to the Proterozoic Era. The Late Cretaceous floodings were connected with a Gulf of Mexico-Arctic transgression. The Bearpaw sediments represent the latest phase of the Late Cretaceous inundations of Western Canada. The Bearpaw sediments, formed during the advance and retreat of this final Late Cretaceous sea in Alberta, subcrop under a large portion of southern and south-central Alberta (see figure 1).

A pioneering study of Bearpaw microfaunas by Wickenden (1932) resulted in the description of five new species of foraminifera from southern Alberta. Loranger and Gleddie (1953) illustrated foraminifera and ostracodes from the Bearpaw Formation of the Cypress Hills. Although several new foraminiferal species were named, the names



STUDY SECTIONS

1.	Oldman River	JW-RR-71-1
2.	Lundbreck	JW-66-19
3.	Castle River	JW-RR-71-2
4.	Waterton River	JW-RR-71-3

Figure 1: INDEX MAP OF SOUTHERN ALBERTA
(after Wall et al., 1971)

they introduced became invalid under the terms of the 1958 International Code of Zoological Nomenclature. Caldwell and North (1964) listed three microfaunal assemblages from the stratal units of the Bearpaw Formation of the South Saskatchewan River Valley of southwestern Saskatchewan. This was followed by a report by North and Caldwell (1970) on the systematics, distribution, and regional relationships of the foraminiferal faunas of the same area. Given and Wall (1971) analyzed both the biostratigraphy and the paleoecology of the microfaunal assemblages collected from the Bearpaw Formation near Castor in south-central Alberta.

The first systematic treatment of Bearpaw megafauna was given by Whiteaves (1885). Dowling (1917) provided lists of marine invertebrates from the Bearpaw Formation of the southern Plains of Alberta and illustrated many of the species. A more complete listing was given by Williams (1930a). The same year, Williams (1930b) gave systematic descriptions of new invertebrates from the Bearpaw Formation. Some of the more important Bearpaw megafaunal elements were illustrated by Warren (1931). Russell and Landes (1940) listed, systematically described, and illustrated many Bearpaw megafaunal elements.

Two important unpublished works on the Bearpaw Formation include a thesis by Anan-Yorke (1969) dealing with the foraminifera of the Bearpaw Formation of the Lethbridge area and a thesis by Harland (1970) dealing with the dinoflagellates and acritarchs of the Bearpaw Formation in southern Alberta.

Location of Samples and Laboratory Techniques

Surface outcrop sections of the Bearpaw Formation were sampled in four localities from southwestern Alberta (figure 1) for microfaunal analysis. A total of 117 samples were collected.

The principle section for the purpose of this study is on the northern bank of the Crowsnest River, NE 1/4, Sec. 26, Tp. 7, R. 2, west of the Fifth Meridian, near Lundbreck, Alberta. A total of 104 samples were taken from this locality (JW 66-19).

Accessory sections are on the Oldman River in SE 1/4, Sec. 11, Tp. 10, R. 2, W 5 Mer. (JW-RR-71-1); on the Castle River in SW 1/4, Sec. 27, Tp. 6, R. 1, W 5 Mer. (JW-RR-71-2); and on the Waterton River in NE 1/4, Sec. 35, Tp. 4, R. 28, W 4 Mer. (JW-RR-71-3). A total of 13 samples were collected from these three localities.

From each sample, 150 grams was weighed and placed in plastic beakers, with detergent and water being added. Breakdown was facilitated by freezing and thawing the mixtures. The samples were then washed through a 200 mesh sieve and dryed. Dry sieving was done with 20, 40, 60, 80, 120, and ±200 sieves. The residues were then picked for microfaunal content.

Photomicrography, Designation and Preservation of Type Material

Photomicrographs were taken on a Carl Zeiss Polarizing Photomicroscope with Kodak Panatomic-X film. The photographs were printed on Kodak F-5 single-weight paper.

Specimens were photographed with reflected light and in some cases were immersed in water to reduce glare and to emphasize morphological details. The ostracodes were whitened with ammonium

chloride prior to photographing.

All photographed specimens have been assigned the letters RR, which are the initials of this writer, and an identifying number ranging from 1 to 60. All material is housed in the micropaleontological collections at the Research Council of Alberta.

CHAPTER TWO

STRATIGRAPHY OF THE BEARPAW FORMATION

Introduction

This study is intimately concerned with the lateral and vertical stratigraphic relationships of the Bearpaw Formation of the southwestern Foothills of Alberta.

The Bearpaw Formation was originally delineated and named by Hatcher and Stanton (1903) in the Bearpaw Mountains of north-central Montana. The Bearpaw Formation there consists of "dark clay shales with many calcareous concretions", and overlies the nonmarine deposits of the Judith River Formation. Lithologic and paleontologic similarities resulted in a correlation of the Bearpaw Formation with a portion of the Pierre Shales.

Hatcher and Stanton also recognized the Bearpaw Formation in the Cypress Hills of southern Alberta. These beds had originally been mapped as Pierre Shales by Canadian geologists (Dawson, 1882-84). Dowling (1917) was the first geologist to use the terms Bearpaw Shales and Bearpaw Formation in Canadian literature.

Regional Setting

The outcrop pattern of the Bearpaw Formation in Alberta (figure 1) may be separated into three main belts or lineaments (Russell, 1950).

The western belt is within the Foothills of the Rocky Mountains. The structural complexity of the Foothills region and the relative

structural incompetence of the Bearpaw strata have made the formational thickness difficult to determine. A total thickness of 915 feet for the Bearpaw Formation is recognized by the writer near Lundbreck. North of the Bow River the Bearpaw Formation is absent.

The central outcrop belt extends from the 49th parallel northward through Lethbridge and Castor to about 50 miles northwest of Edmonton. Link and Childerhose (1931) recorded 726 feet of Bearpaw Formation at Lethbridge. To the north, the Bearpaw Formation is 470 feet thick near Castor (Given and Wall, 1971) and thins westerly to 196 feet near Didsbury (Irish and Harvard, 1968), and to only 150 feet near Rimbey (Williams and Burk, 1964, well log data).

The eastern outcrop belt is separated by the Sweetgrass Arch from the central belt and extends into Saskatchewan from southeast Alberta. On the southwest side of the Cypress Hills, the Bearpaw Formation is 1030 feet thick (Loranger and Gleddie, 1953).

In the southern Alberta Plains, the Bearpaw Formation marine shales separate the nonmarine Oldman River and St. Mary River Formations. This relationship can be traced into the Foothills south of the Bow River where the Bearpaw Formation separates the Belly River and St. Mary River Formations (Russell, 1939; Russell and Landes, 1940). In the Foothills north of the Bow River, the Bearpaw Formation is absent and the nonmarine Edmonton Group rests directly on the Belly River Formation.

Eastward from Alberta, the Bearpaw Formation is recognized in southwestern Saskatchewan and is represented in Manitoba by the upper part of the Riding Mountain Formation (Jeletzky, 1971).

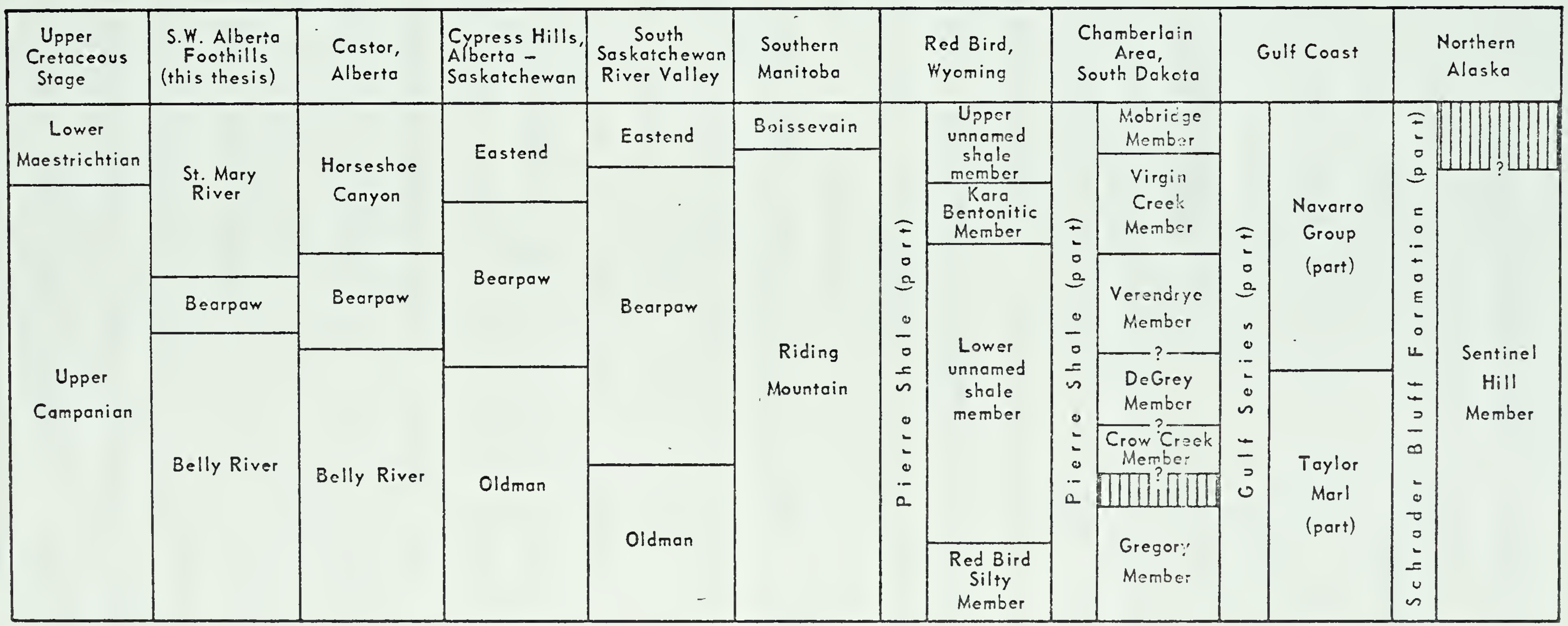


Figure 2: REGIONAL CORRELATION OF THE BEARPAW FORMATION
(after Given and Wall, 1971)

The northern extent of the Bearpaw sea has not been definitely established. Williams and Burk (1964) considered the Bearpaw sea to have extended just to the north of Edmonton. Gill and Cobban (1966), however, postulated that a Late Campanian sea extended from the Gulf Coast area to the Arctic Islands. Work by Jeletzky (1968; 1971) would also suggest a northern extension of the Bearpaw sea into the Arctic region during the Late Campanian.

In Alberta, the lower contact of the Bearpaw Formation and the underlying nonmarine Belly River or Oldman Formations is sharp and apparently conformable. This relationship has been assumed to represent a rapid Bearpaw transgression (Russell, 1939; Lines, 1963; Jeletzky, 1971). The contact is placed at the top of the uppermost coal-bearing and carbonaceous shale beds of the Belly River Formation (Ower, 1960, *fide* Williams and Burk, 1964). Douglas (1950) places the contact where "silty, green and grey shales of the Belly River Formation change to rubbly, dark grey, marine shales". Douglas (op. cit.) also notes that "thin beds of carbonaceous shale and coal seams occur in the upper 20 feet of Belly River beds".

The upper contact of the Bearpaw Formation with the nonmarine and brackish Horseshoe Canyon, St. Mary River, or Eastend Formations is gradational and diachronous. These formations lie above the Bearpaw Formation in the northern, southern, and eastern sections respectively (Williams and Burk, 1964). In addition, the Bearpaw Formation is replaced to the north by the Horseshoe Canyon Formation of the Edmonton Group. Present information (North and Caldwell, 1970; Given and Wall, 1971) would suggest the possibility of homotaxial relationships across both the upper and lower contacts.

Description

Link and Childerhose (1931) described the Bearpaw Formation of the Lethbridge area and recognized a lower and an upper division. The lower one-third consists of well-bedded dark shales and the upper two-thirds consist of light bluish, sandy shales containing three sandstone members. In ascending order, these latter sandstone members were named the Magrath, Kipp, and Ryegrass Sandstones. Russell and Landes (1940) described the Bearpaw Formation and the associated megafauna of southeastern Alberta. Lines (1963) discussed the distribution of the Bearpaw Formation and provided regional correlations across central and southern Alberta. Given (1969) provides both a comprehensive summary and bibliography of Bearpaw studies in Canada.

The published stratigraphic studies of the Bearpaw Formation of the southwestern Foothills of Alberta include those of Hage (1940; 1943; 1945) and Douglas (1950; 1951). Hage (1943) described the Bearpaw Formation of the Cowley map areas as consisting of "dark grey marine shales with some reddish brown concretions". He estimated the Bearpaw Formation to be about 800 feet thick along the Crowsnest River (sampled section JW-66-19) with a net stratigraphic exposure of 600 feet. Hage (1940) also estimated that there was 600 feet of Bearpaw strata along the Castle River (sampled section JW-RR-71-2).

Work by Wall and assistants (pers. comm.) has shown that the Bearpaw Formation near Lundbreck (sampled section JW 66-19) consists of approximately 915 feet of strata, with only 520 feet of net stratigraphic exposure (see figure 3). The lithology consists of a dark grey marine shale with bands of concretions and bentonite.

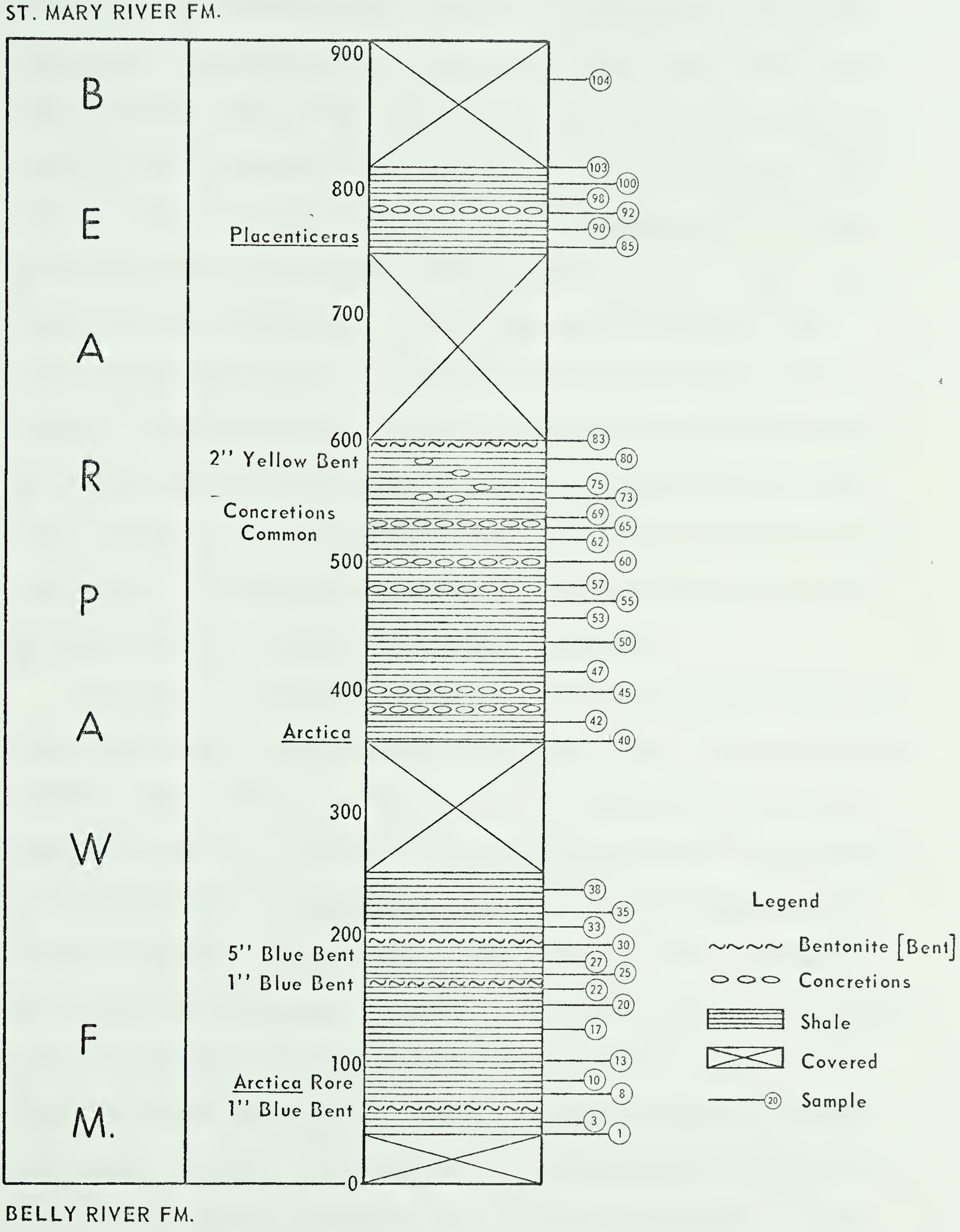


Figure 3: LUNDBRECK SECTION (JW 66-19)
(measured by J.H. Wall and L.S. Eliuk)

Other outcrops of the Bearpaw Formation throughout the study area examined by the writer in 1971 consist of a lithology similar to that of the Lundbreck section. Hage (1943) and Douglas (1950) both noted sandstone beds in the Bearpaw Formation along the Oldman River (sampled section JW-RR-71-1). Douglas (op. cit.) noted that "a few, massive, medium- to coarse-grained, grey sandstone beds are interstratified with the dark grey, fissile, marine shale". Hage (ibid) suggested that the sandstone present represents "shallower sea conditions to the north". Although the sea may well have been shallower to the north, the writer considers the sandstones of Hage and Douglas (supra) to be faulted wedges of the overlying St. Mary River Formation. In fact, Douglas (ibid) notes that "there is little lithological difference between the basal St. Mary River and upper Bearpaw sandstones" [of Hage and Douglas (supra)].

In general, the Bearpaw Formation consists of a dark grey marine shale, often with reddish brown concretionary bands. The concretions are often fossiliferous and contain *Arctica ovata* or *Placenticeras*. Sandstone members are present in the Bearpaw Formation in many areas, but to the writer's knowledge are not present in the southwestern Alberta Foothills. In southwestern Saskatchewan, five sand members are present in the Bearpaw Formation. The sands generally are quartzitic, fine-grained, and often glauconitic (Caldwell, 1968). Lines (1963) described two sandstone intervals from the Bearpaw Formation near Castor, Alberta. The lower sand is medium-grained, glauconitic, and the upper sand is bentonitic and typically "nonmarine". These are the second Castor sandstone and the first Castor sandstone respectively of Given and Wall (1971). Given and Wall (op. cit.) describe

the sands as "greyish-green, generally medium-grained, partly glauconitic and somewhat bentonitic". In the Cypress Hills, Lines (1963) describes the Thelma and Oxarart Members in the Bearpaw Formation as "medium-grey, grey to yellow weathering sandstone". The Oxarart Member "can be traced eastward into Saskatchewan where it eventually thins out into a glauconitic horizon". No sandstones are present in the Lundbreck section.

All Bearpaw sands mentioned above are glauconitic and therefore possibly represent the results of shoaling and winnowing, with removal of the finer clastics locally. In this regard, the continuous shale section of the Lundbreck locality and of the present study area can be regarded as reflecting a reduction in current and wave energy, inhibiting further sorting. This leaves the coarser clastic particles distributed evenly throughout the section.

The sands within the Bearpaw Formation on the Oldman River reported by Douglas (1950) are described by him as "fine- to medium-grained, grey sandstones". These are regarded by this writer as part of the St. Mary River Formation as their lithology is in marked contrast with other Bearpaw sands. They are lithologically similar to the sands of the St. Mary River Formation. Douglas (op. cit.) also noted this similarity.

Age and Correlation

The age of the Bearpaw Formation has been established as Late Campanian and Early Maestrichtian by Jeletzky (1968). Jeletzky suggests that the Bearpaw Formation is encompassed by most of the *Baculites compressus* Zone of Landes (Landes, 1940; Cobban and Reeside,

1952) in the Plains and Foothills regions of western North America, and extends upward into the *Baculites grandis* Zone of Cobban and Reeside (1952) in southwestern Saskatchewan.

A potassium-argon age determination on a bentonite (Folinsbee *et al.*, 1960; 1961) 65 feet above the base of the Bearpaw Formation gave a date of 75±4 million years. Further Bearpaw Formation dating (Shafiqullah *et al.*, 1964; Folinsbee *et al.*, 1965; Folinsbee *et al.*, 1970) in papers discussing the age of the Cretaceous-Tertiary boundary in Western Canada is shown in figure 4. Folinsbee *et al.* (1965) sampled four bentonites near Lethbridge and three age dates were determined. An age of 73 m.y. was obtained near the base of the formation, an age of 71 m.y. immediately above the Magrath Sandstone, and an age of 68 m.y. immediately above the Kipp Sandstone. Folinsbee *et al.* (op. cit.) also dated six bentonites from the Bearpaw Formation of the Cypress Hills. The bentonites give an age of 72 m.y. near the base of the Manyberries Member and an age of 66 m.y. within the Belanger Member. Two similar dates were determined from bentonites in the Bearpaw Formation of the South Saskatchewan River Valley of Saskatchewan (Folinsbee *et al.*, op. cit.). The age of 69 m.y. was determined for both the lower part of the Beechy Member (basal Bearpaw Formation) and the Snakebite Member of the Bearpaw Formation. In addition, Folinsbee *et al.* (op. cit.) dated two Bearpaw bentonites from northern Montana. The bentonite from the lower one-third of the Montana section gave a date of 71 m.y., and the bentonite near the top of the section gave a date of 68 m.y. (figure 4).

The ages recovered from bentonite dating are slightly anomalous, especially in the light of paleogeographic interpretations by North

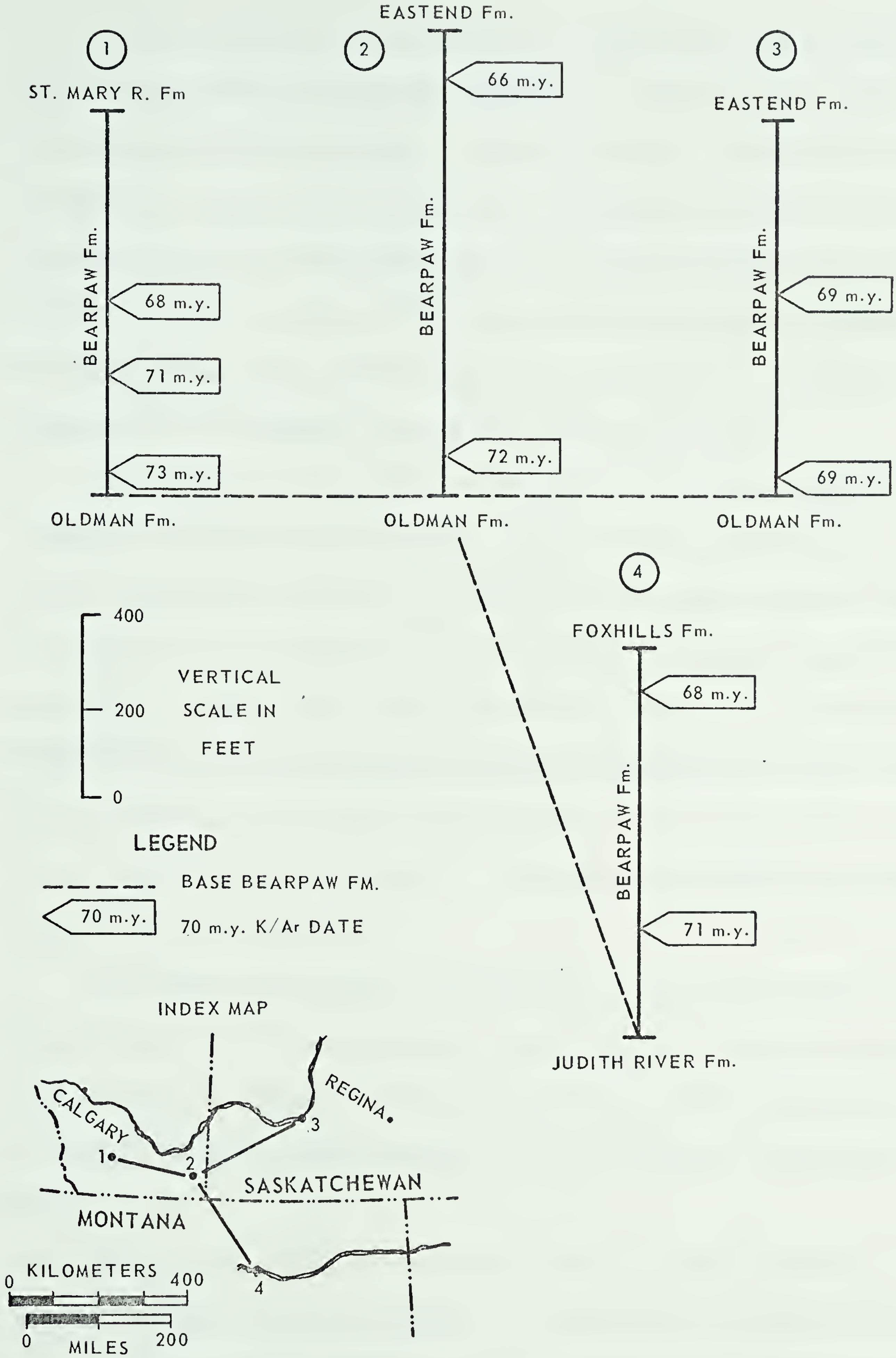


Figure 4: BEARPAW BENTONITE K/Ar DATES
(after Folinsbee et al., 1965)

and Caldwell (1970) and Given and Wall (1971) using the foraminiferal assemblages within the Bearpaw Formation. The age dates suggest a transgression which proceeded from west to east. The foraminiferal assemblages suggest the transgression proceeded from east to west. In general, the age dates show that the Bearpaw transgression began 72-73 m.y. ago in southern Alberta and that the ensuing regression was diachronous across Alberta from north to south. The Bearpaw sea completed its withdrawl from Alberta before 65 m.y. ago.

The regional correlations of selected formations of Upper Campanian and Lower Maestrichtian stages from the Gulf Coast to Alaska are shown in figure 2. The base of the Upper Campanian stage is assumed to be at the base of the *Baculites mclearni* Zone (Gill and Cobban, 1966). The correlation chart (figure 2) is limited in extent from only the base of the *Baculites gregoryensis* Zone in the Upper Campanian to the top of the *Baculites clinolobatus* Zone in the Lower Maestrichtian, although the formations may extend beyond this range, here and elsewhere.

The Bearpaw Formation of Saskatchewan is correlative with the upper Taylor and the lower Navarro Group strata of the North American type Cretaceous section of the Gulf Coast area. The Bearpaw Formation of Alberta is more closely equated with the strata of the Navarro Group.

Payne *et al.* (1951) divided the Schrader Bluff Formation of northern Alaska into three members. From oldest to youngest these are the Rogers Creek, the Barrow Trail, and the Sentinel Hill Members. The Sentinel Hill Member more than encompasses the time of deposition of the Bearpaw Formation in Western Canada.

The Pierre Shale of the west-central United States represent Campanian-Maestrichtian marine deposition. The time represented by the Pierre Shale more than spans the time of Bearpaw deposition in Canada. The correlation of the Red Bird, Wyoming section, which can be considered to be a type Pierre Shale section (Gill and Cobban, 1966), and the Lundbreck section (this thesis) is given in figure 5. The Pierre Shale in Wyoming ranges from the top of the *Scaphites hippocrepis* Zone to the top of the *Baculites clinolobatus* Zone. The Bearpaw Formation in southwestern Saskatchewan is restricted to the interval between the *Didymoceras nebrascense* Zone and the *Baculites grandis* Zone, according to North and Caldwell (1970). The Bearpaw Formation near Lethbridge (Gill and Cobban, 1966) spans only the *Baculites compressus*, *B. cuneatus*, and *B. reesidei* Zones. The present writer suggests that the Bearpaw Formation in southwestern Alberta is further restricted to the *Baculites cuneatus* Zone and the lower part of the *Baculites reesidei* Zone. This latter correlation is based on the relation of the foraminiferal assemblages to the ammonite zones (North and Caldwell, 1970). The ammonite zonation near Lethbridge, combined with the foraminiferal zonation of the same area (Anan-Yorke, 1969) provides a good basis for correlation of the ammonite and foraminiferal faunas in that area. This calibration can be extrapolated to the Lundbreck section (figure 5).

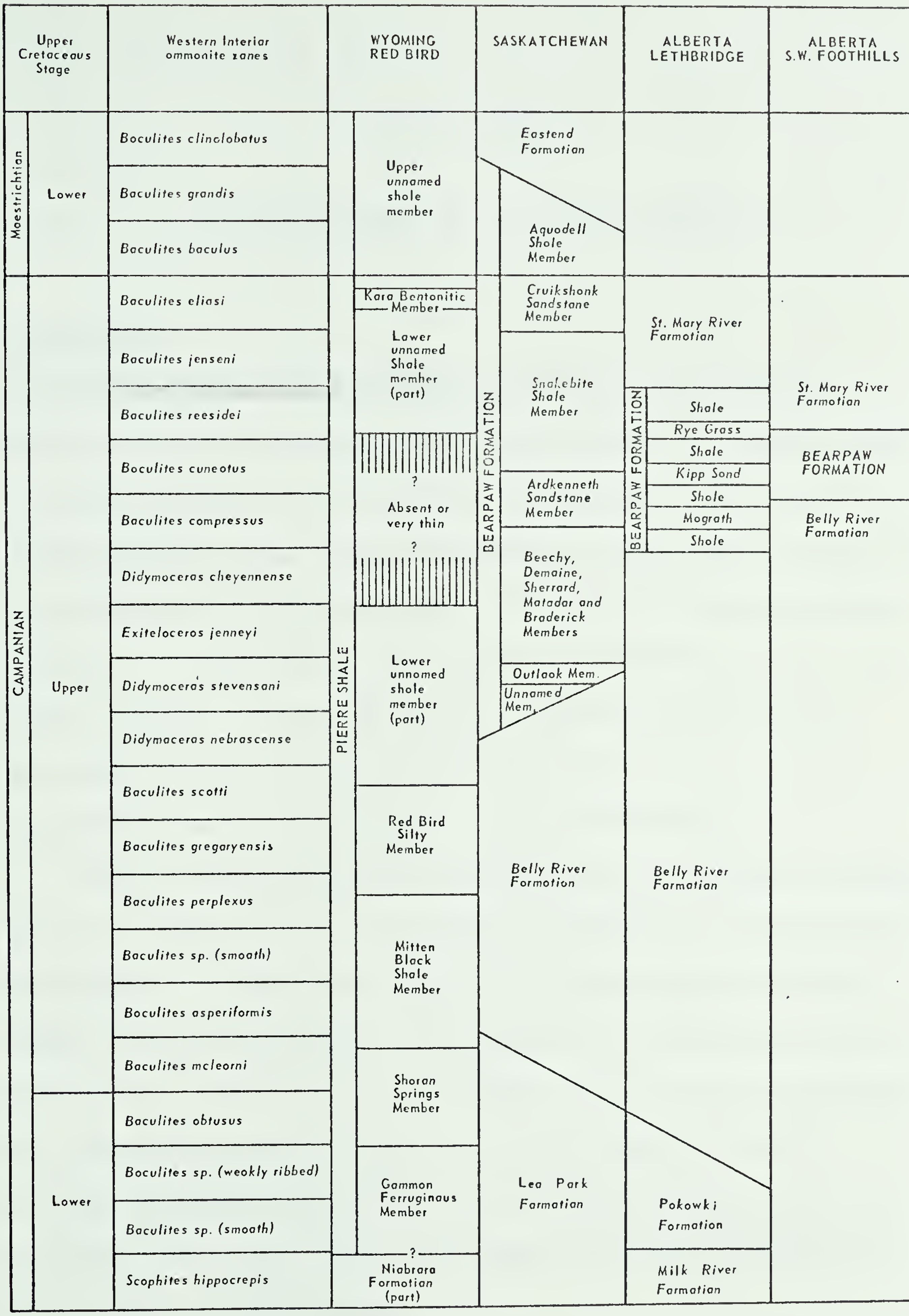


Figure 5: CORRELATION OF BEARPAW FORMATION AND UPPER CRETACEOUS AMMONITE ZONES (in part after Gill and Cobban, 1966; North and Caldwell, 1970)

CHAPTER THREE

MICROPALEONTOLOGY OF THE BEARPAW FORMATION

Introduction

In this chapter, the microfossil content of the Bearpaw Formation in the southwestern Foothills of Alberta is analyzed and a zonation based on the microfossils is proposed. Correlations and comparisons with other Bearpaw microfaunal studies provides important information about the depositional history of the Bearpaw Formation in Canada. Preservation of the specimens studied was fair to good in most samples. Of the four sections examined, three of those, the Lundbreck, Castle River, and Oldman River sections, yielded foraminifera and all four sections yielded ostracodes.

Previous Bearpaw microfaunal studies have been largely concerned with the establishment of foraminiferal zonations for the purpose of correlations. Although this aspect is an important part of this study, the biostratigraphic and paleoecologic implications of the foraminiferal populations are considered to be of primary importance. The long-ranging nature of many of the Late Campanian species detracts from their index value for correlative purposes, but does not detract from their value with respect to biostratigraphic and paleoecologic interpretations.

Wickenden (1932) described the first foraminiferal species from the Bearpaw Formation. Loranger and Gleddie (1953) began the first

biostratigraphic work on Bearpaw microfaunas. More recently, the Bearpaw Formation has attracted the attention of North and Caldwell in Saskatchewan, and Wall and his co-workers in Alberta. North and Caldwell (1964) reported on the biostratigraphy of the Bearpaw Formation of the South Saskatchewan River Valley of southwestern Saskatchewan. This was followed by the establishment of three faunal assemblages within the Bearpaw Formation of the same area (North and Caldwell, 1970). From the base to the top of the Bearpaw Formation respectively, these are a *Gaudryina bearpawensis* fauna, an *Anomalinoides* sp. fauna, and a *Haplophragmoides excavata* fauna.

Given and Wall (1971) established two assemblage zones from within the Bearpaw Formation near Castor. These are a lower *Eoeponidella strombodes* assemblage and an upper *Cassidella tegulata* - *Marginulina* cf. *dorsata* assemblage.

Anan-Yorke (1969) studied the foraminiferal assemblages within the Bearpaw Formation near Lethbridge. He reports four microfaunal assemblages consisting of a *Dorothia* sp. "Zone" near the base of the formation, a *Gavelinella* sp. "Zone" immediately above, followed by an interval with arenaceous foraminifera, and finally an *Anomalinoides* sp. "Zone".

Foraminifera from the Lundbreck Section (JW 66-19)

The exposed and sampled portions of the Bearpaw Formation at Lundbreck can be separated into three intervals by the intervening covered portions (figure 3). The lowermost interval encompasses the exposure from 40 to 250 feet above the base of the Bearpaw Formation

and samples 1 to 38 inclusive. The middle interval extends from 355 to 595 feet above the base and includes samples 40 to 83 inclusive. The uppermost interval extends from 745 to 815 feet above the base and includes samples 85 to 103. An isolated sample (104) was taken in a heavily talused interval at 885 feet above the base.

The range chart (figure 6) displays the occurrences of the species found in the Lundbreck section. Of the 26 species present, eight arenaceous and two calcareous species occur in all three sampled intervals. These 10 species found throughout the Bearpaw Formation are:

Gaudryina bearpawensis Wickenden

Haplophragmoides fraseri Wickenden

H. linki Nauss

H. kirki Wickenden

Praebulimina venusae (Nauss)

Saccammina sp. A

S. sp. B

S erovaina orbicella (Bandy)

Trochammina albertensis Wickenden

Verneuilinoides bearpawensis (Wickenden)

Only one species, *Eoeponidella strombodes* Tappan, is restricted to the lowermost interval.

Seven species are restricted to the middle interval. These are:

Dorothia sp.

Eoeponidella linki Wickenden

Haplophragmoides sp. B

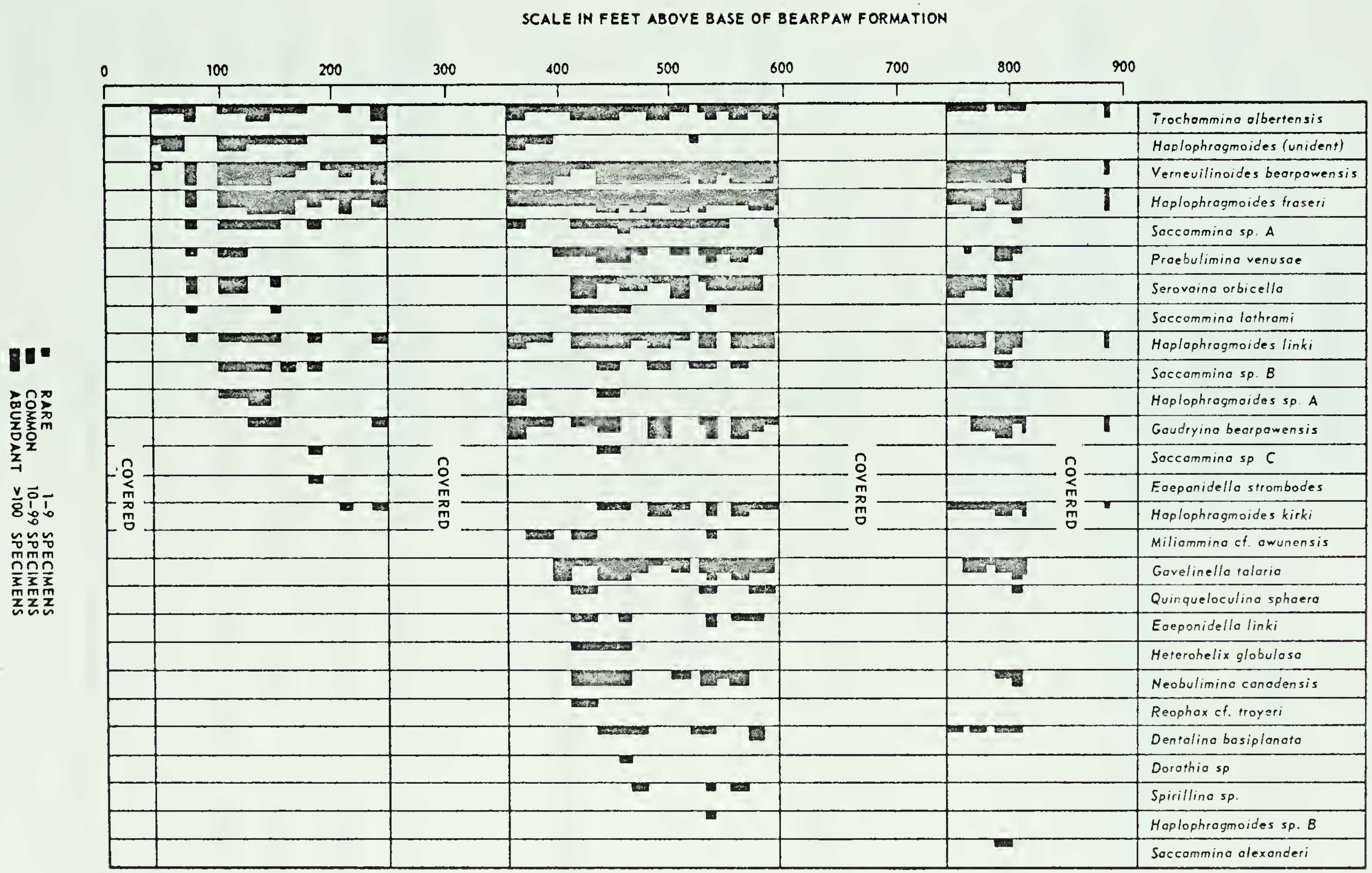


Figure 6: RANGE CHART OF THE FORAMINIFERAL SPECIES FROM THE BEARPAW FORMATION, LUNDBRECK, ALBERTA (JW 66-19)

Heterohelix globulosa (Ehrenberg)

Miliammina sp. cf. *M. awunensis* Tappan

Reophax sp. cf. *R. troyeri* Tappan

Spirillina sp.

One species, *Saccammina alexanderi* (Loeblich and Tappan) is restricted to the uppermost interval.

Three species are restricted to the lower and middle intervals combined. These are:

Haplophragmoides sp. A

Saccammina lathrami Tappan

S. sp. C

Four species are restricted to the middle and upper intervals combined. These are:

Dentalina basiplanata Cushman

Gavelinella talaria (Nauss)

Neobulimina canadensis Cushman and Wickenden

Quinqueloculina sphaera Nauss

Foraminifera from the Castle River Section (JW-RR-71-2)

A total of seven samples were taken from the outcrop, but since neither the base or top of the Bearpaw Formation is exposed at this locality, the stratigraphic levels of the samples cannot be ascertained. Sample 1 was taken near the top end of the exposure and Sample 7 at the bottom end, with the remaining samples spaced in between.

The samples were badly weathered and a loss of some calcareous forms is a distinct possibility. The ranges of the species present

are shown in figure 7.

Five species were found in all samples. These are:

Gaudryina bearpawensis Wickenden

Haplophragmoides fraseri Wickenden

H. linki Nauss

Trochammina albertensis Wickenden

Verneuilinoides bearpawensis (Wickenden)

One species, *Haplophragmoides kirki* Wickenden, was found in all samples except sample 3, and *Saccammina* sp. A was found in samples 1, 4, and 7.

One species, *Dorothia* sp., was restricted to sample 4. *Haplophragmoides* sp. B was restricted to sample 5, and *Gavelinella talaria* (Nauss) was found only in samples 4 and 7. The species *Praebulimina venusae* (Nauss) and *Saccammina* sp. B are restricted to sample 7.

Foraminifera from the Oldman River Section (JW-RR-71-1)

The section exposed on the Oldman River is badly contorted by folds and faults, and is rather useless for biostratigraphic purposes. Only two samples were taken. The first, sample 1, was taken about 15 feet below the faulted contact of the Bearpaw Formation with the overlying St. Mary River Formation. The second sample was taken near the base of the exposed Bearpaw Formation.

Only two species were found to occur in both samples. These are *Haplophragmoides fraseri* Wickenden, and *Trochammina albertensis* Wickenden.

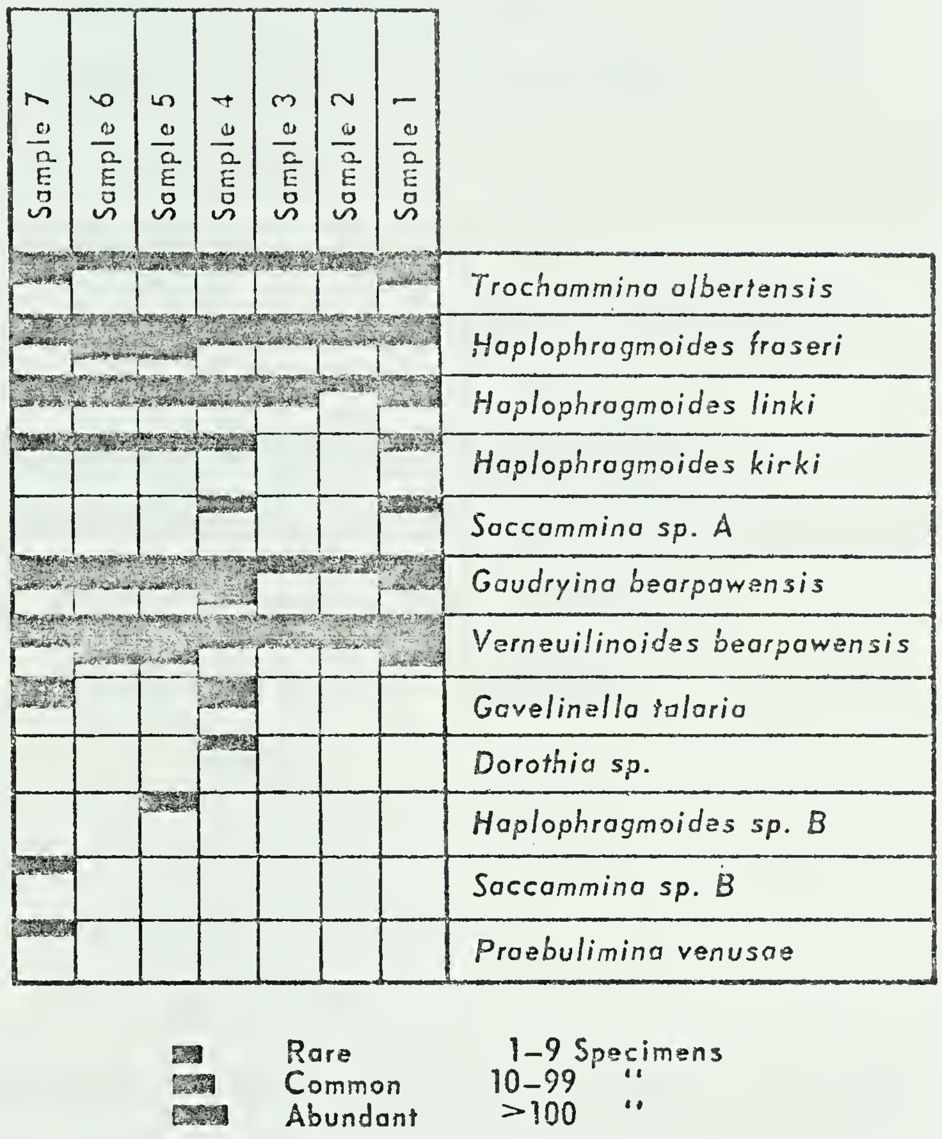


Figure 7: RANGE CHART OF FORAMINIFERAL SPECIES FROM THE BEARPAW FORMATION, CASTLE RIVER (JW-RR-71-2)

Seven other species are present in sample 2. These are:

Dorothia sp.

Gaudryina bearpawensis Wickenden

Gavelinella talaria (Nauss)

Haplophragmoides kirki Wickenden

H. linki Nauss

Saccammina sp. A

Verneuilinoides bearpawensis (Wickenden)

Ostracodes from the Lundbreck Section (JW 66-19)

Five species of marine ostracodes belonging to two genera are present in the Lundbreck section. These are:

Haplocytheridea sp. A (98-790)

H. sp. B (178)

H. sp. C (178-540)

Veenia sp. A (98-468)

V. sp. B (455-490)

The distribution of each species throughout the section (in feet above the base of the Bearpaw Formation) is given in parentheses following the species.

Ostracodes from the Castle River Section (JW-RR-71-2)

Two species, *Veenia* sp. B, and *Haplocytheridea* sp. C were found near the base of the exposed Bearpaw Formation, and *Veenia* sp. B was also recovered from near the top of the exposure.

Ostracodes from the Oldman River Section (JW-RR-71-1)

Only *Veenia* sp. B was found near the top of the Bearpaw Formation at this locality.

Ostracodes from the Waterton River Section (JW-RR-71-3)

Five fresh to brackish water species of ostracodes, belonging to three genera, were found in the basal part of the Bearpaw Formation at this locality. These are:

Reconcavona sp. A

R. sp. B

Pontocypris sp.

Cypridea sp. A

C. sp. B

Proposed Zonation of the Bearpaw Formation

The zonation of the Bearpaw Formation in southwestern Alberta is based on the ostracodes from the Waterton River section, and on the foraminifera from the Lundbreck section. The fauna from the Oldman and Castle Rivers sections add supporting evidence for the zonation.

Three faunal assemblages are recognizable in the Bearpaw Formation of the southwestern Alberta Foothills. These are, from bottom to top, an ostracode assemblage, an arenaceous foraminifera assemblage, and a *Gavelinella talaria* assemblage.

The ostracode assemblage, which is entombed within the lowermost 40 feet of the Bearpaw Formation in the study area, is well developed on the Waterton River (JW-RR-71-3). The fauna consists of three

fresh to brackish water ostracode genera, including two species of *Cypridea*, two species of *Reconcavona*, and one species of *Pontocypris*. These species are all restricted to this lowermost stratigraphic level in the Bearpaw Formation in the study area.

The arenaceous foraminifera assemblage extends upwards from 40 to 395 feet above the base of the Bearpaw Formation at Lundbreck. The fauna is dominated by 11 arenaceous species and includes only three calcareous species.

The arenaceous species are:

Gaudryina bearpawensis Wickenden

Haplophragmoides fraseri Wickenden

H. kirki Wickenden

H. linki Nauss

H. sp. A

Miliammina sp. cf. *M. awunensis* Tappan

Saccammina lathrami Tappan

S. sp. A

S. sp. B

S. sp. C

Trochammina albertensis Wickenden

Verneuilinoides bearpawensis (Wickenden)

The calcareous species are:

Eoeponidella strombodes Tappan

Praebulimina venusae (Nauss)

Serovaina orbicella (Bandy)

The only species restricted to this assemblage is *Eoeponidella strombodes* Tappan.

The *Gavelinella talaria* assemblage extends from 395 feet above the base of the Bearpaw Formation at Lundbreck to the top of the sampled portion of the section (885 feet above the base). The fauna includes 16 arenaceous species and 9 calcareous species.

The arenaceous species are:

Dorothia sp.

Gaudryina bearpawensis Wickenden

Haplophragmoides fraseri Wickenden

H. kirki Wickenden

H. linki Nauss

H. sp. A

H. sp. B

Miliammina sp. cf. *M. awunensis* Tappan

Reophax sp. cf. *R. troyeri* Tappan

Saccammina alexanderi (Loeblich and Tappan)

S. lathrami Tappan

S. sp. A

S. sp. B

S. sp. C

Trochammina albertensis Wickenden

Verneuilinoides bearpawensis (Wickenden)

The calcareous species are:

Dentalina basiplanata Cushman

Eoeponidella linki Wickenden

Gavelinella talaria (Nauss)

Heterohelix globulosa (Ehrenberg)

Neobulimina canadensis Cushman and Wickenden

Praebulimina venusae (Nauss)

Quinqueloculina sphaera Nauss

Serovaina orbicella (Bandy)

Spirillina sp.

The species restricted to this *Gavelinella talaria* assemblage are:

Dentalina basiplanata Cushman

Dorothia sp.

Eoeponidella linki Wickenden

Gavelinella talaria (Nauss)

Haplophragmoides sp. B

Heterohelix globulosa (Ehrenberg)

Neobulimina canadensis Cushman and Wickenden

Quinqueloculina sphaera Nauss

Reophax sp. cf. *R. troyeri* Tappan

Saccammina alexanderi (Loeblich and Tappan)

Spirillina sp.

Species common to both the arenaceous foraminifera assemblage and the *Gavelinella talaria* assemblage are:

Gaudryina bearpawensis Wickenden

Haplophragmoides fraseri Wickenden

H. kirki Wickenden

H. linki Nauss

H. sp. A

Miliammina sp. cf. *M. awunensis* Tappan

Praebulimina venusae (Nauss)

Saccammina lathrami Tappan

S. sp. A

S. sp. B

S. sp. C

Serovaina orbicella (Bandy)

Trochammina albertensis Wickenden

Verneuilinoides bearpawensis (Wickenden)

Age and Correlation

Several of the species present are long-ranging forms which inhabited the seas of the western interior of North America throughout much of the Upper Cretaceous. *Neobulimina canadensis* and *Praebulimina venusae* are two examples. Other species are more restricted in both time and distance domains. *Serovaina orbicella* and *Heterohelix globulosa* are restricted to the Campanian and Maestrichtian stages. *Eoeponidella linki* and *Quinqueloculina sphaera* are regarded as Middle and Late Campanian index fossils. The species *Gaudryina bearpawensis* indicates a Late Campanian age of part of the Bearpaw Formation in southwestern Alberta.

The correlation of the microfossil assemblages established from the Bearpaw Formation in the southwestern Foothills of Alberta with those established from the Bearpaw Formation elsewhere is difficult. The Bearpaw faunal assemblages are based on microfossils whose occurrences are largely environmentally controlled. The problem is complicated by the long-ranging nature of some of the species.

The species recorded in the present study are not restricted to any one of the three assemblages recorded by North and Caldwell (1970) from the Bearpaw Formation in Saskatchewan. *Gaudryina bearpawensis* occurs only in their *Gaudryina bearpawensis* fauna but occurs throughout the Lundbreck section. Species which are common in their *Anomalinoides* sp. fauna, such as *Gavelinella talaria*, *Serovaina orbicella*, and *Dentalina basiplanata* occur in the Lundbreck section. It is evident that the Bearpaw faunal assemblages utilized by North and Caldwell (op. cit.) cannot be recognized in the present study area. It is suggested that for correlative purposes, the assemblages present in the southwestern Foothills of Alberta are probably time equivalents of the *Anomalinoides* sp. fauna of North and Caldwell (op. cit.).

For correlative purposes, the *Anomalina* sp. Zone of Loranger and Gleddie (1953) from the Bearpaw Formation of the Cypress Hills probably encompasses all of the assemblages of the southwestern Foothills of Alberta.

Given and Wall (1971) described a lower *Eoeponidella strombodes* assemblage and an upper *Cassidella tegulata-Marginulina* cf. *dorsata* assemblage from the Bearpaw Formation in east central Alberta. The arenaceous foraminiferal assemblage in the present study correlates with a part of their *Eoeponidella strombodes* assemblage on the basis of the restricted occurrence of *Eoeponidella strombodes* within both of these assemblages. The *Gavelinella talaria* assemblage of the present study likely correlates with the upper part of the *Eoeponidella strombodes* assemblage and the lower part of their

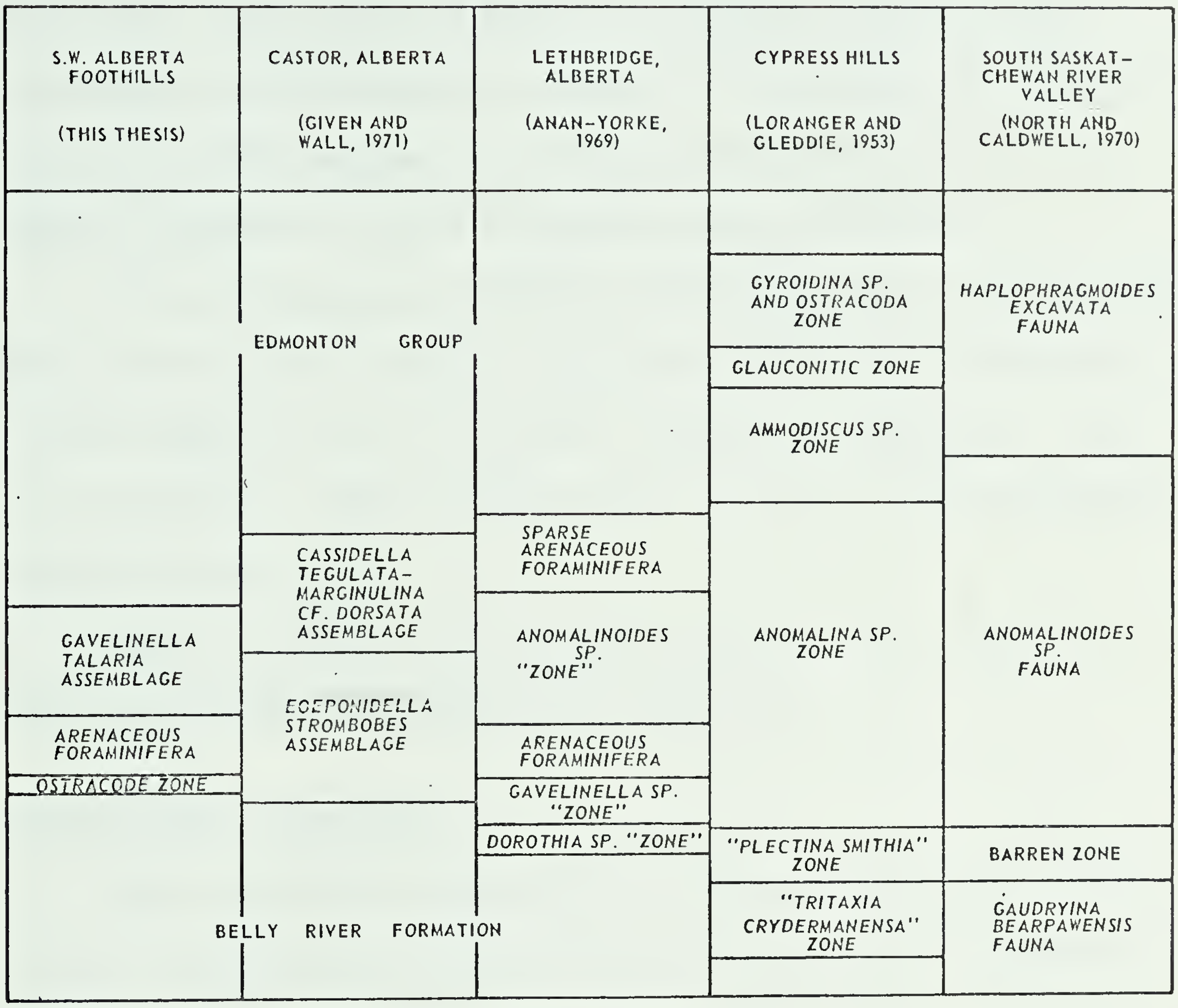


Figure 8: BEARPAW FORMATION MICROFAUNAL CORRELATIONS IN SOUTHERN ALBERTA AND SASKATCHEWAN (in part after Given and Wall, 1971)

Cassidella tegulata-Marginulina cf. *dorsata* assemblage.

The ostracode assemblage of the present study is a homotaxial unit which is correlative with part of the *Dorothia* sp. "Zone" of Anan-Yorke (1969) from the base of the Bearpaw Formation near Lethbridge. Brackish water ostracodes were found in this zone by Anan-Yorke. The homotaxial and transgressive nature of this unit makes it difficult to use for accurate time correlation.

The *Anomalinoides* sp. "Zone" of Anan-Yorke (op. cit.) correlates with the *Gavelinella talaria* assemblage of the present area, each in turn underlain by an arenaceous foraminifera assemblage. The *Gavelinella*? sp. "Zone" of Anan-Yorke (op. cit.) is not recognized in the present study.

The correlations of the Bearpaw Formation across Alberta and into Saskatchewan are summarized in figure 8.

Foraminiferal Comparisons

Some geographical occurrences of selected species that were found in the Bearpaw Formation of the present study are shown in figure 9.

The fauna from the Bearpaw Formation of the southwestern Foothills of Alberta is closely related to the Arctic or boreal fauna (Tappan, 1962). A few species are common to both the present study and that of Mello (1971) in the western interior of the United States, and also to that of Cushman (1946) in the Gulf Coast area. Several species are common to both the present study and that of Sliter (1968) in the California area.

BEARPAW SPECIES FROM S.W. ALBERTA (THIS THESIS)	ALASKA TAPPAN (1962)	WYOMING MELLO (1971)	CALIFORNIA SLITER (1968)	GULF COAST CUSHMAN (1946)
Trochammina albertensis	●	○	○	○
Verneuilinoides bearpawensis	○	○	○	○
Haplophragmoides fraseri	○	○	●	○
Praebulimina venusae	●	○	●	○
Seravoina orbicella	○	○	●	○
Saccammina lathrami	●	○	○	○
Haplophragmoides linki	●	○	○	○
Gaudryina bearpawensis	○	○	○	○
Eoeponidella strombodes	●	○	○	○
Haplophragmoides kirki	○	●	●	○
Miliammina sp. cf. M. awunensis	●	○	○	○
Gavelinella talaria	●	○	○	○
Quinqueloculina sphaera	●	○	○	○
Eoeponidella linki	●	○	○	○
Heterohelix globulosa	●	●	●	●
Neobulimina canadensis	●	●	●	●
Reophax sp. cf. R. troyeri	●	○	○	○
Dentalina basiplanata	●	●	●	●
Saccammina alexanderi	○	○	○	○

● *Species present*

○ *Species absent*

Figure 9 : GEOGRAPHICAL OCCURRENCES OF THE FORAMINIFERAL SPECIES

This suggests that the Gulfian forms could not easily migrate into the study area as there seems to have been one or more barriers (land, currents, salinity variations, etc.) restricting movements. The migration of the Arctic forms was much easier, suggesting that there were few, if any, migratory barriers between Alberta and Alaska during the Late Campanian. Also, a connection of the Bearpaw and Pacific seas appears plausible, if not necessary, to explain occurrences of species common to Alberta and California during the Late Campanian.

CHAPTER FOUR

PALEOECOLOGY

Introduction and Paleoecologic Model

The concepts of relating foraminiferal populations to their environments were popularized by Phleger (1960). He attempted to provide an ecological model based on the distribution of Recent foraminiferal populations. When considering paleoecology, it is imperative to realize that the population observed is not a biocoenosis, but is rather a thanatocoenosis, which is further restricted in its components by fossil preservation and by collecting techniques. Therefore, it is not possible to apply directly all of the relationships observed between Recent foraminiferal populations and their environments to fossil foraminiferal populations and their paleo-environments.

The concepts and relationships presented here are based largely on the paleoecologic study of the Alaskan Cretaceous foraminifera by Tappan (1962). As well, the studies and views of Mello (1969), North and Caldwell (1970), and Given and Wall (1971) have been taken into account by the present writer. Tappan (1962) noted that in shallow water, the barriers affecting the distribution of foraminifera are more numerous than in the open ocean. These barriers include "intervening oceanic depths, peninsulas of land, unfavorable sea bottom, suspended sediment and water freshening at river mouths in

addition to the temperature control".

Since the Bearpaw Formation is generally regarded to be a relatively shallow water deposit, some of the barriers and other influences affecting shallow water faunas were operative upon Bearpaw faunas. The depth factor is not of primary importance but the near-shore to off-shore transition becomes crucial. As the temperature is likely to change very little across this transition, factors such as salinity, turbulence and currents, and turbidity are considered to be of utmost importance in considering the paleoecology of the Bearpaw Formation in the southwestern Foothills of Alberta.

i. Salinity as a Limiting Environmental Factor

In modern coastal areas, low salinity reduces the number of species, but the more tolerant species show an increase in the number of individuals present.

In general, calcareous species are affected by very slight changes in salinity. The calcareous tests become "chitinous" rather than calcareous if the salinity is much reduced, and are less likely to be preserved, resulting in a fossil arenaceous assemblage (Revelle and Fairbridge, 1957, *fide* Tappan, 1962). As well, the arenaceous tests are poorly cemented in a low salinity environment. This results in a test susceptible to crushing and distortion and commonly of rough texture.

ii. Turbulence and Currents as Limiting Environmental Factors

"When surface sediments are thrown into suspension by turbulence, the lesser density and the shape of Foraminifera allow them to settle

more slowly than quartz sands so that they rest at the surface. In muddy sediments they may be buried. If buried to a depth not exceeding 5 to 7 times the diameter of the test in sandy sediments they are able to escape. If buried more deeply, they die when the oxygen supply becomes insufficient" (Tappan, 1962, p. 124). The lack of oxygen causes deposition of blue-black sulphides on the walls of the tests or causes the tests to become infilled with pyrite.

In shallow water, strong off-shore currents may prevent planktonic foraminifera from being washed into the shallow water sediments. In some shallow water areas of the world, planktonic foraminifera form a prominent part of the assemblage if off-shore currents are not operable.

iii. Turbidity as a Limiting Environmental Factor

Turbidity has the largest inhibiting effect on the calcareous foraminiferal assemblages. The light penetrating the water, thereby affecting the rate of photosynthesis, controls the amount of food made available to the foraminifera.

Stainforth (1952, *fide* Tappan, 1962) presented evidence that arenaceous foraminiferal assemblages dominated by large robust species are turbidity controlled. The families characteristic of this type of environment, according to Stainforth (op. cit.), are the Rhizamminidae, Reophacidae, Ammodiscidae, Lituolidae, Textulariidae, Verneuilinidae, and Valvulinidae.

Paleoecology of the Bearpaw Formation in Southwestern Alberta

Based on the above relationships and the faunas observed from the Bearpaw Formation of the study area, it is now possible to make some comments on the paleoecology of the Bearpaw Formation in southwestern Alberta and on the movement of the Late Campanian Bearpaw sea in southwestern Alberta.

The presence of brackish water gastropods and ostracodes in the lower 40 feet of the Bearpaw Formation on the Waterton River indicates that the transgression was gradual with the initial Bearpaw sediments having been deposited in a saline lake environment (deltaic or estuarial) with fresh water supplied to the area from distributaries. Grekoff (1956, p. 80) shows the genus *Cypridea* to be common in estuary channels. This form, present at the Waterton River locality, would indicate that the lowermost part of the Bearpaw Formation is not a marine deposit, but rather a supralittoral deposit. For ecologic purposes, we are designating this the lowermost ostracode realm.

The term realm is used here to encompass the areal and vertical (or homotaxial) extent of the deposits of an environment characterized by a recognizable and distinctive fauna. It is therefore a term used to integrate the concepts of the fauna and their environment during the deposition of the sediments.

The lowest observed marine conditions established at Lundbreck within the Bearpaw Formation are 40 feet above the base of the formation. The foraminifera of the Lundbreck section provide good ecologic indicators throughout the Bearpaw Formation.

Figure 10 demonstrates the ratios of arenaceous and calcareous species and specimens in the Lundbreck section. The arenaceous species and specimens dominate the assemblage from 40 to 410 feet above the base of the Bearpaw Formation. For ecologic purposes, this can be termed the lower arenaceous foraminiferal realm.

The calcareous species and specimens achieve parity with their arenaceous counterparts from 410 to 580 feet above the base of the Bearpaw Formation. This can be termed the middle calcareous foraminiferal realm.

The arenaceous components again dominate the assemblage above 580 feet and this can be termed the upper arenaceous foraminiferal realm.

Mello (1969) and North and Caldwell (1970) found similar foraminiferal distributions in the Pierre Shale of South Dakota and in the Bearpaw Formation of southwestern Saskatchewan respectively. To them this relationship suggested a sequence of rather shallow, off-shore water environments, with the associated arenaceous fauna, followed by the calcareous suites, representing a change to somewhat deeper water conditions.

This does not seem to be the case for the Bearpaw Formation in southwestern Alberta. A plot of the number of families represented in each sample is given in figure 11. Mello (1969) suggests that such a plot is a good test of near-shore versus off-shore relationships since the number of families present in a sample is a good indicator of faunal diversity. The results show the sediments from 40 to 410 feet above the base of the Bearpaw Formation were deposited in a

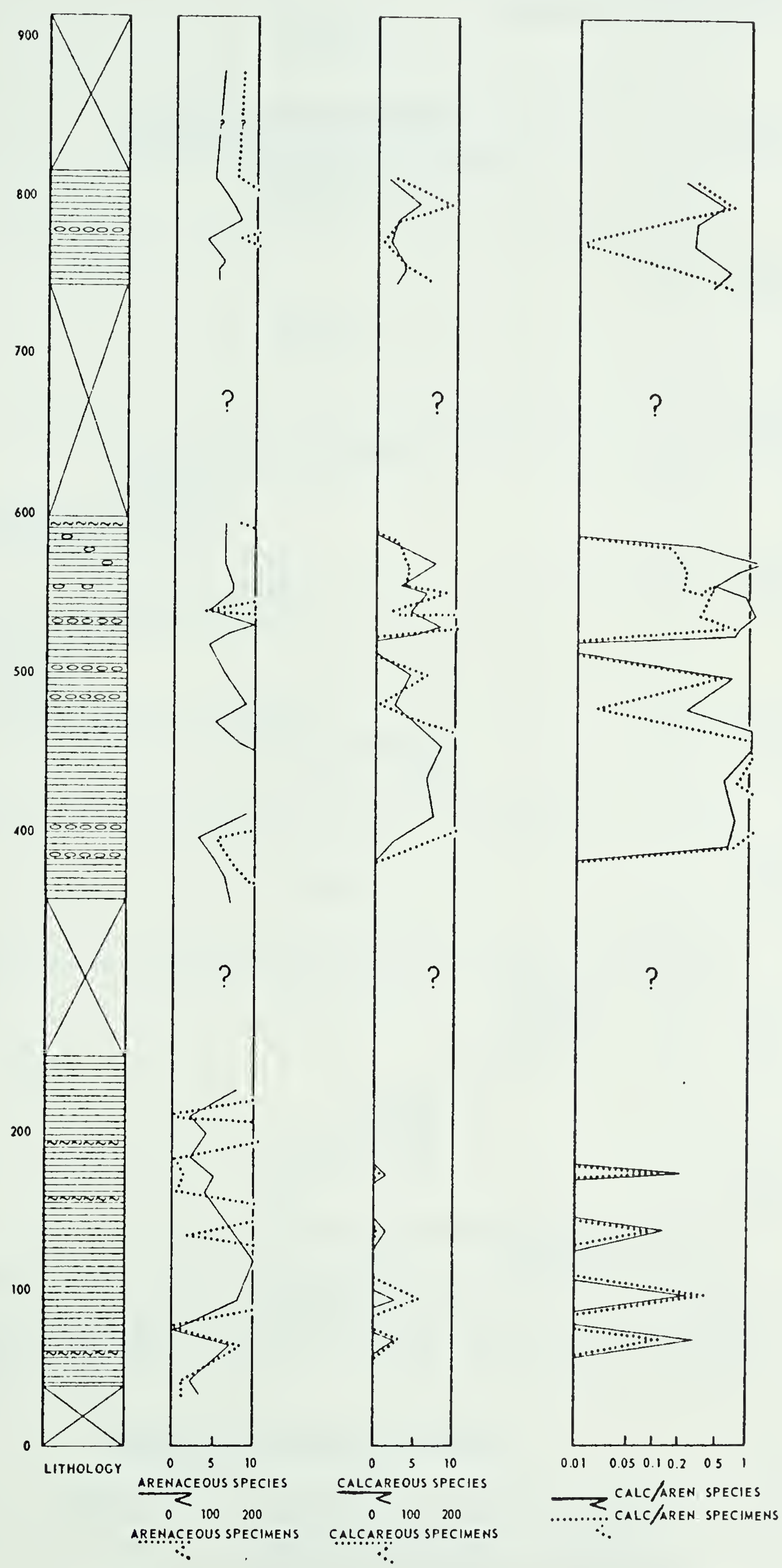


Figure 10: FORAMINIFERAL POPULATIONS, BEARPAW FORMATION, LUNDBRECK

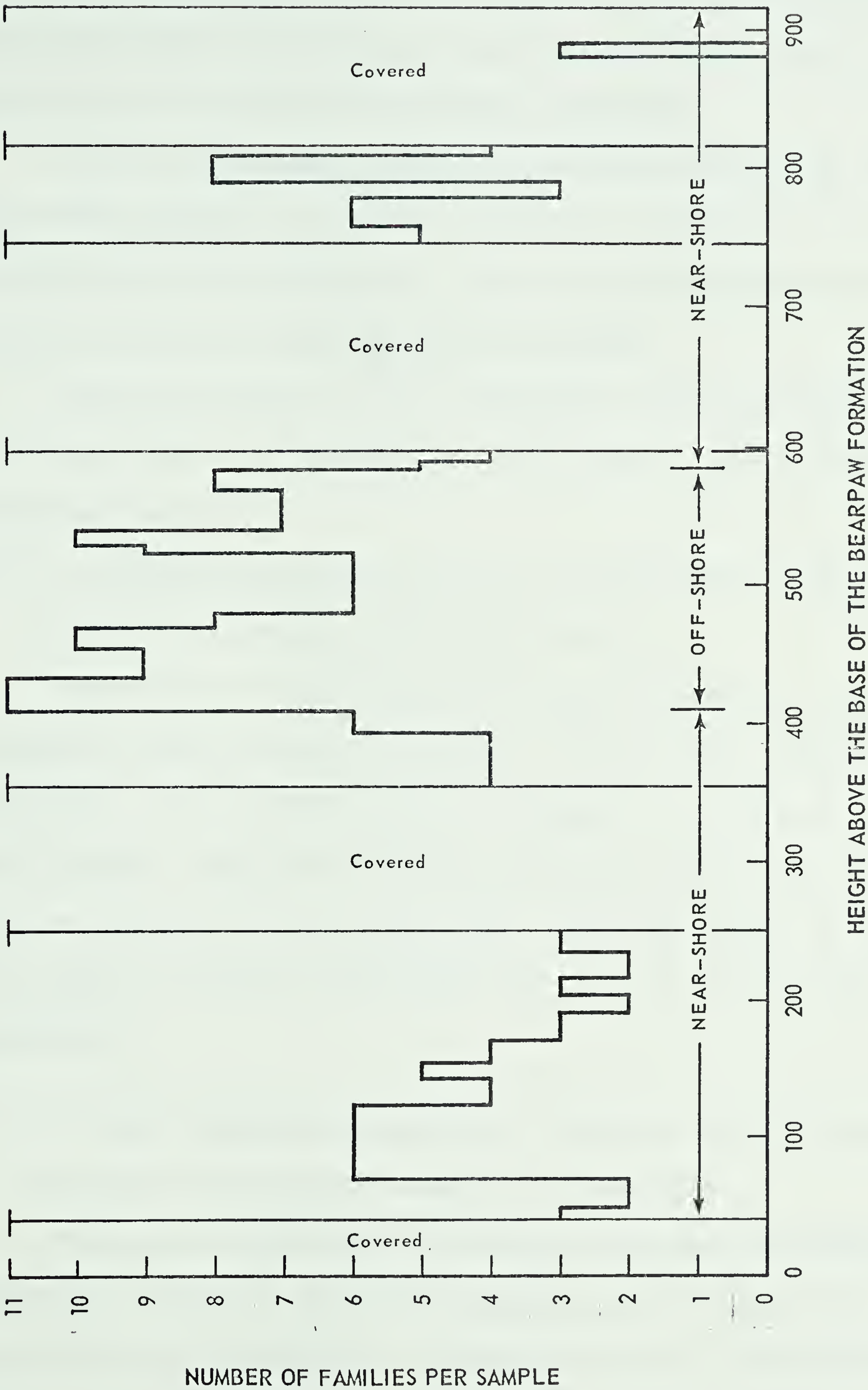


Figure 11: FORAMINIFERAL FAMILY NUMBERS
BEARPAW FORMATION, LUNDBRECK

near-shore environment. This is followed by off-shore sediments from 410 to 580 feet, followed in turn by near-shore sediments above 580 feet above the base of the Bearpaw Formation.

The lower arenaceous foraminiferal realm is within the earlier near-shore sediments, the middle calcareous foraminiferal realm is within the off-shore sediments, and the upper arenaceous foraminiferal realm is within the later near-shore sediments.

It is now possible to make some comments about environmental limiting factors and relationships within each of the four realms mentioned above.

1) The lowermost ostracode realm (0 to 40 feet above the base of the Bearpaw Formation at Waterton River)

The presence of fresh to brackish water ostracodes in the lowermost Bearpaw Formation indicates a supralittoral environment of deposition. The crushed nature and fragmentation of the specimens would suggest deposition in 'tidal pools' where the salinity was quite low but the agitation and energy level were quite high. In this environment, salinity is definitely the limiting factor on the faunal assemblage.

2) The lower arenaceous foraminiferal realm (40 to 410 feet above the base of the Bearpaw Formation at Lundbreck)

The fauna in this realm is completely dominated in numbers by arenaceous specimens, especially *Haplophragmoides fraseri* and *Verneuilinoides bearpawensis*. *Serovaina orbicella, Praebulimina venusae,* and *Eoeponidella strombodes* are the only calcareous forms found in this realm. The sizes of the calcareous tests are small,

which Walton (1964) regards to be indicative of marginal marine environments.

The arenaceous dominance and the crushed preservation of many of the forms suggests that the life in this near-shore environment was controlled largely by the salinity of the water. The streams emptying into the Bearpaw sea at the nearby shoreline lowered the salinity of the water and only the more tolerant forms could survive. The off-shore currents prevented planktonics from being washed into the area. Turbidity in part may have limited the number of calcareous forms. This is the littoral environment of Tappan (1962).

3) The middle calcareous foraminiferal realm (410 to 580 feet above the base of the Bearpaw Formation at Lundbreck)

This off-shore environment is dominated by *Haplophragmoides fraseri*, *H. linki*, *Verneuilinoides bearpawensis*, *Gaudryina bearpawensis*, *Serovaina orbicella*, *Gavelinella talaria* and *Neobulimina canadensis*. Other calcareous forms such as *Eoeponidella linki* and *Heterohelix globulosa* appear only in this realm. This suggests that salinity was normal in this environment and that off-shore currents were still strong enough to allow only a minor number of planktonic foraminifera to inhabit the area. The most important environmental limiting factor in this realm would appear to be turbulence. Many of the specimens are pyritized in this interval and this suggests rapid burial with a lack of oxygen. This is characteristic of the inner sublittoral environment of Tappan (1962).

4) The upper arenaceous foraminiferal realm (above 580 feet)

This realm is similar to the earlier arenaceous realm in that it represents a near-shore environment but it was definitely not as harsh as the lower realm. Some calcareous species, such as *Gavelinella talaria*, *Dentalina basiplanata*, and *Neobulimina canadensis* which were established in the off-shore environment, manage to survive in this environment but in lesser proportions. It is suggested that this environment is transitional between the littoral and inner sublittoral environments. It may be expected that turbidity and currents, and to a lesser extent salinity, were the controlling factors in this environment.

The large quantities of bentonite and tuffs in the Upper Cretaceous would indicate that ash falls were an important contributor to the turbidity.

These ecologic realms demonstrate that the sediments of the Bearpaw Formation in the Lundbreck area are the result of a single transgressive-regressive cycle. The species are sufficiently long-ranging to ensure that this relationship should be recognizable throughout the Bearpaw Formation of the southwestern Foothills of Alberta and the surrounding areas.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS

During the last decade, researchers in the United States have done much to interpret the complex depositional history of Upper Cretaceous sedimentation in the west-central United States and contiguous areas. Canadian workers are now interpreting the history north of the 49th parallel.

North and Caldwell (1970), Given and Wall (1971), Anan-Yorke (1969), and Harland (1970) advanced the Canadian studies of the Late Campanian - Early Maestrichtian Bearpaw Formation in southwestern Saskatchewan, east-central Alberta, south-central Alberta, and southern Alberta respectively. However, a crucial gap remained in the depositional picture. The microfauna of the Bearpaw Formation in the Foothills of southwestern Alberta was little known.

The writer is undertaking this study to close this gap. This area in southwestern Alberta is important since it represents the westernmost extension of the Late Campanian sea into an area adjacent to a tectonic belt which, at the time of Bearpaw deposition, was active west of the Rocky Mountain Trench.

The Bearpaw Formation of the southwestern Foothills of Alberta yields a microfauna dominated by foraminifera, the majority of these being arenaceous, and supplemented by ostracodes and minor occurrences of diatoms and radiolaria. The majority of the

foraminiferal species are long-ranging Upper Cretaceous forms which reinhabited the Late Campanian Bearpaw sea within the study area, following the transgression which inundated the Belly River deltaic complex. A close resemblance of the foraminiferal elements to the members of the Arctic Cretaceous fauna (Tappan, 1962) suggests an unrestricted connection of the Bearpaw sea with an Arctic sea. This resemblance may also be due in part to similar environments of deposition. Some restricted connection with a Gulfian sea is postulated. The restrictions acted as barriers against gross faunal migration. The microfauna of the Bearpaw sea in southwestern Alberta seems to reflect similarities with Pacific microfauna.

On the basis of microfaunal associations within the Bearpaw Formation in the southwestern Foothills of Alberta, a sequence of three microfaunal assemblages have been designated. These are: an ostracode assemblage, which is represented in the lowermost 40 feet of strata at the Waterton River locality; an arenaceous foraminifera assemblage, which extends from the top of the ostracode assemblage to 395 feet above the base of the Bearpaw Formation at Lundbreck; and an arenaceous-calcareous *Gavelinella talaria* foraminifera assemblage, which extends from 395 to 885 feet above the base of the section at Lundbreck (the top of the sampled portion).

All three assemblages appear to be within the span of the *Anomalinoides* sp. Zone of North and Caldwell (1970) and the *Anomalina* sp. Zone of Loranger and Gleddie (1953). The ostracode assemblage is an homotaxial association related to the advance of the shoreline facies and has been recognized near Lethbridge by Anan-Yorke (1969)

within his so-called *Dorothia* sp. "Zone".

The microfaunal evidence indicates that sediments within the Bearpaw Formation in the southwestern Foothills of Alberta were formed in a succession of four major depositional environments. These environments reflect both the transgression and the regression of the Bearpaw sea. The four environments are as follows:

i. The basal 40 feet of the Bearpaw Formation were apparently deposited in a supralittoral environment, and more specifically in tidal pools where the salinity was too low for foraminifera to survive. Only ostracodes and gastropods were observed in the deposits of this environment.

ii. Following the above set of conditions, marine conditions were introduced into the area and deposition occurred in a littoral environment where salinity was low but turbidity was high. This environment influenced the pattern of the fauna collected from 40 to 410 feet above the base of the Bearpaw Formation in the Lundbreck section.

iii. The continuing transgression of the Bearpaw sea westward resulted in the establishment of an off-shore environment at the Oldman and Castle Rivers and at Lundbreck. The association of arenaceous and calcareous foraminiferal species indicates that deposition occurred in an inner sublittoral environment. The sediments deposited in this environment are present in the interval from 410 to 580 feet above the base of the Bearpaw Formation at Lundbreck.

iv. The ensuing eastward regression of the Bearpaw sea resulted in depositional environment which was transitional between the inner

sublittoral environment and the littoral environment. The sediments of this environment occur beyond 580 feet above the base of the Bearpaw Formation at Lundbreck. Arenaceous foraminifera dominate the microfaunal assemblage.

The Bearpaw transgression appears to have been gradual and diachronous across southwestern Alberta and perhaps across much of southern Alberta. The regression from southwestern Alberta was more rapid. The rapid withdrawl of the Bearpaw sea is suggested since there is no long-ranging littoral or supralittoral environment expressed in the upper part of the Bearpaw Formation.

Whether a transgression or regression is either rapid or slow is relative. If the Bearpaw Formation in the southwestern Foothills of Alberta only is considered, the transgressive sediments comprise more than one-third of the total sedimentary thickness. Since this corresponds to about one-third of the time of Bearpaw sedimentation in this area, the transgression might be termed slow or gradual. However, in contrast, the Bearpaw flooding in Saskatchewan lasted much longer. The period of deposition represented by the introductory transgressive sediments of southwestern Alberta accounts for only one-thirtieth of the time interval of Bearpaw deposition in Saskatchewan. Thus the transgression into western Alberta, with respect to Saskatchewan and eastern Alberta, could be considered to be rapid. The distinction is important and the terms rapid or gradual should be used only with respect to a designated set of geological and geographical coordinates.

The rate of sedimentation of the Bearpaw Formation in southwestern

Alberta was rapid with respect to the rates of sedimentation of the Bearpaw Formation in eastern Alberta and southwestern Saskatchewan, since southwestern Alberta was proximal to the westerly source area. The sedimentation of the Bearpaw Formation in southwestern Alberta is restricted to the *Baculites cuneatus* Zone and the lower part of the *Baculites reesidei* Zone (figure 5). The Bearpaw sea had withdrawn completely from southwestern Alberta before the correlative beds to the *Baculites jenseni* Zone were laid down.

CHAPTER SIX

SYSTEMATIC PALEONTOLOGY

Introduction

The classification of foraminifera in the following systematic descriptions, to the generic level, follows exclusively the classification of the Treatise on Invertebrate Paleontology, Part C, Protista 2 (1964). Below the generic level, specimens are either described as hypotypes of previously published species, or as sp. cf. previously published species, or simply have been assigned a genus and *nomen aperta* letter. The latter cannot be assigned with assurity to any of the published species which were reviewed. No attempt has been made to formally define any species as new in this study.

Seventeen arenaceous foraminifera species, included in six families and eight genera, and nine calcareous species, included in five families and eight genera are described. Size ranges are given for a species if more than 100 specimens were recovered from the Lundbreck section.

Two diatoms are described and are classified after Given and Wall (1971).

One radiolarian is described and classified after the Treatise on Invertebrate Paleontology, Part D, Protista 3 (1954).

Ten ostracode species, belonging to six genera, are described and classified according to the Treatise on Invertebrate Paleontology,

Part Q, Arthropoda 3 (1961). Description of the ostracodes is limited to a consideration of external features only as poor preservation and a lack of free valves did not permit observation of the interiors.

Phylum PROTOZOA

Subphylum SARCODINA Schmarda, 1871

Class RETICULAREA Lankester, 1885

Subclass GRANULORETICULOSIA de Saedeleer, 1934

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage and Herouard, 1896

Superfamily AMMODISCACEA Reuss, 1862

Family SACCAMMINIDAE Brady, 1884

Subfamily SACCAMMININAE Brady, 1884

Genus SACCAMMINA M.Sars, 1869

SACCAMMINA ALEXANDERI (Loeblich and Tappan)

Plate 2, figure 13

? *Proteonina alexanderi* Loeblich and Tappan, 1950, Univ. Kansas Paleont. Contrib ., Protozoa, Article 3, p. 5, pl. 1, figs. 1, 2.

Proteonina sp. cf. *P. alexanderi* Loeblich and Tappan. Stelck and Wall, 1955, Res. Coun. Alberta Rept. 70, p. 52, pl. 1, figs. 5, 6.

? *Saccammina alexanderi* (Loeblich and Tappan). Eicher, 1960, Peabody Museum of Natural History, Yale Univ., Bull. 15, pl. 3, figs. 1, 2 --- Eicher, 1966, Contrib. Cushman Found. Foram. Res., vol. 17, pt. 1, p. 20, pl. 4, figs. 1, 2.

Saccammina sp. cf. *S. alexanderi* (Loeblich and Tappan). Wall, 1967, Res. Coun. Alberta Bull. 20, p. 40, pl. 8, figs. 16, 17; pl. 14, figs. 17, 18.

Saccammina alexanderi (Loeblich and Tappan). North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 14, pl. 1, fig. 6 ---- Morris, 1971, Micropaleontology, vol. 17, no. 3, p. 264, pl. 1, figs. 4-5.

Description: Test a single chamber, flask shaped, not compressed, neck prominent, thin, elongate, slightly tapering; wall arenaceous, coarse-grained, poorly sorted, slightly pyritized, surface rough; aperture terminal, on neck; color brown.

Dimensions:

	Length (mm.)	Width (mm.)	Neck (mm.)
Hypotype RR 1 (fig. 13)	0.73	0.38	0.25

Locality: Hypotype RR 1 is from the Lundbreck section, sample 98, 790 feet above the base of the Bearpaw Formation.

Distribution: This species is very rare in the study area, the only specimen recovered being the figured specimen. *Saccammina alexanderi* has been found most commonly in much older rocks in North America, mainly Albian and Cenomanian age rocks of the western interior. Its presence in the Bearpaw Formation of Saskatchewan (North and Caldwell, 1970) extended its range through the Upper Cretaceous Series. This species was also reported by Anan-Yorke (1969) from the Bearpaw Formation near Lethbridge, Alberta.

SACCAMMINA LATHRAMI Tappan

Plate 2, figure 15

Saccammina lathrami Tappan, 1960, Bull. Am. Assoc. Petroleum Geol., vol. 44, no. 3, p. 289, pl. 1, figs. 1, 2 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 129, pl. 29, figs. 9-12 --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 4, p. 11, pl. 1, fig. 3 --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 15, pl. 1, fig. 4 --- Morris, 1971, Micropaleontology, vol. 17, no. 3, p. 264, pl. 1, figs. 6, 10.

Description: Test a single chamber, subovate in outline, flattened with central depressed area; wall finely agglutinated with considerable cement, smooth; aperture round, terminal, produced on a short poorly defined neck; color white.

Dimensions

	Length (mm.)	Width (mm.)	Neck (mm.)
Hypotype RR 2 (fig. 15)	0.42	0.30	0.07

Locality: Hypotype RR 2 is from the Lundbreck section, sample 53, 455 feet above the base of the Bearpaw Formation.

Distribution: This species is quite rare in the study area (7 specimens) but is present in the middle portion of the Lundbreck section. In the type area of *S. lathrami* of the Arctic slope of Alaska, the species ranges only as high as the Turonian Seabee Formation. However, North and Caldwell (1964; 1970) report finding

this species from beds as late as Campanian in Saskatchewan, thus extending the range from late Albian to late Campanian.

Remarks: The specimens examined appear to be slightly smaller than those from the type area. North and Caldwell (1970, p. 15) also found a smaller size in the Bearpaw specimens from Saskatchewan.

SACCAMINA sp. A

Plate 2, figures 16, 17

Description: Test a single chamber, circular in outline, often flattened with compression during fossilization creating a central depressed area; wall finely agglutinated, fairly smooth with much cement; aperture not observed; color white to buff-white.

Dimensions:

	Max. diam. (mm.)	Min. diam. (mm.)
Figured specimen RR 34 (fig. 16)	0.24	0.22
Figured specimen RR 35 (fig. 17)	0.28	0.27

Locality: Figured specimen RR 34 is from the Lundbreck section, sample 47, 411 feet above the base of the Bearpaw Formation.

Figured specimen RR 35 is also from the Lundbreck section, sample 53, 455 feet above the base.

Distribution: This species is common in small numbers (114

specimens) throughout the Bearpaw Formation in this area, being found at the Oldman and Castle Rivers sections as well as at the Lundbreck section.

Remarks: This species is generally quite small, however some specimens attain diameters slightly larger than those of the figured specimens, perhaps representing a more adult stage of development. It appears to be conspecific with the *Saccammina* sp. of Given and Wall (1971, p. 522) which they found in the lower Bearpaw Formation from their Bow River section.

SACCAMMINA sp. B

Plate 2, figures 18, 19

Description: Test a single chamber, ovate in outline, flattened and slightly depressed in center; wall agglutinated, medium grained, considerable cement, quite rough; aperture round, terminal, produced on a short but very well defined neck; color white.

Dimensions

	Length (mm.)	Width (mm.)	Neck (mm.)
Figured specimen RR 36 (fig. 19)	0.50	0.42	0.07
Figured specimen RR 37 (fig. 18)	0.48	0.38	0.05

Locality: Figured specimen RR 36 is from the Castle River section, sample 7, near the base of the Bearpaw Formation.

Figured specimen RR 37 is from the Lundbreck section, sample 57, 481 feet above the base of the Bearpaw Formation.

Distribution: This species occurs sporadically throughout the Bearpaw Formation near Lundbreck, and only in small numbers. It is also present in the Castle River section. Twenty-five specimens were recovered.

Remarks: This species resembles *S. complanata* (Franke) but is not amorphous. As well, the neck on *S. complanata* appears to taper more than the neck on this species. This species resembles the *Saccammina* sp. 1 of Wall (1967) except that the neck in that species is less well defined.

SACCAMMINA sp. C

Plate 2, figure 12

Description: Test a single chamber, elongate, flattened, slightly depressed in center; wall agglutinated, medium grained, large amount of cement, rough; aperture round, terminal, produced on a short, poorly defined neck; color grey to brown.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen RR 38 (fig. 12)	0.80	0.45

Locality: The figured specimen is from the Lundbreck section, sample 50, 435 feet above the base of the Bearpaw Formation.

Distribution: This species is very rare, being found only in one other sample, 178 feet above the base of the Bearpaw Formation. Only five specimens were found.

Remarks: This species is larger than other *Saccammina* species found in the study area, and is quite poorly preserved, sometimes becoming distorted during fossilization causing the neck to be twisted to one side.

Superfamily LITUOLACEA de Blainville, 1825

Family HORMOSINIDAE Haeckel, 1894

Genus REOPHAX de Montfort, 1808

REOPHAX sp. cf. R. TROYERI Tappan

Plate 2, figure 14

? *Reophax troyeri* Tappan, 1960, Am. Assoc. Petroleum Geol. Bull., vol. 44, no. 3, p. 291, pl. 1, figs. 10, 12 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 133, pl. 30, figs. 11, 13.

Description: Test elongate, uniserial, straight, usually with four chambers, circular in cross section and increasing uniformly in size, final chamber much longer and produced terminally to form a neck; sutures distinct, depressed, transverse; wall finely agglutinated,

roughly finished, pyritized; aperture simple, terminal, round, at end of neck.

Dimensions:

	Length (mm.)	Width (mm.)
Figured specimen RR 39 (fig. 14)	0.50	0.16

Locality: The figured specimen is from the Lundbreck section, sample 47, 411 feet above the base of the Bearpaw Formation.

Distribution: This species is rare at this locality with only five specimens observed, all in the same sample. Originally recorded by Tappan (1960, p. 291) from the Topagoruk Formation (Albian) of Alaska, this species was also found in the Bearpaw Formation near Lethbridge by Anan-Yorke (1969, p. 42).

Remarks: The specimens at this locality have a greater length/width ratio than the Alaska specimens, but otherwise are very similar.

Family RZEHAKINIDAE Cushman, 1933

Genus MILIAMMINA Heron-Allen and Earland, 1930

MILIAMMINA sp. cf. M. AWUNENSIS Tappan

Plate 2, figures 5-7

? *Miliammina awunensis* Tappan, 1957, U.S. Natl. Mus. Bull. 215, p. 210, pl. 67, figs. 19-21 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 159, pl. 36, figs. 20-24.

Description: Test free, elongate, flattened, ovate in outline, quinqueloculine in plan; chambers narrow, elongate, each a half coil in length; sutures indistinct, depressed; wall finely arenaceous, surface smoothly finished; aperture simple, opening at end of final chamber; color white.

Dimensions:

	Length (mm.)	Width (mm.)	Thickness (mm.)
Figured specimen RR 40 (fig. 5-7)	0.28	0.18	0.10

Locality: The figured specimen is from the Lundbreck section, sample 47, 411 feet above the base of the Bearpaw Formation.

Distribution: This species is very rare, with only six specimens in three samples from the middle portion of the section observed. Originally described by Tappan (1957, p. 215) from Alaska and again in 1962 (p. 159), it occurs in Albian and Cenomanian rocks in Alaska.

Remarks: Although quite similar to *Miliammina awunensis* Tappan, the specimens observed are poorly preserved and too few in number to define the extension of the range of this species into the Campanian. The specimens differ from *M. manitobensis* Wickenden in being smoothly finished, more finely agglutinated, and having narrow chambers of equal diameter throughout.

Family LITUOLIDAE de Blainville, 1825

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES FRASERI Wickenden

Plate 1, figures 3-6

Haplophragmoides fraseri Wickenden, 1932, Trans. Roy. Soc. Can., 3rd ser., vol. 26, sec. 4, p. 86, pl. 1, figs. 2a, b --- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 21-22, pl. 3, figs. 1a, b --- Trujillo, 1960, Jour. Paleont., vol. 34, no. 2, p. 305, pl. 43, figs. 6a, b --- Sliter, 1968, Univ. Kans., Paleont. Contr., Art. 7, Protozoa, p. 44, pl. 2, figs. 1a, b --- Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 523, pl. 1, figs. 1-4.

Description: Test medium to large, nautiloid, usually compressed; periphery rounded, partly angular due to compression; test partly evolute with each coil partially overlapping the previous one; chambers distinct, nine or ten in the last formed coil; sutures distinct, slightly curved, nearly radial, slightly depressed; wall composed of fine angular grains, much cement, quite smooth; color usually yellowish.

Dimensions

	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype RR 3 (fig. 3, 4)	0.37	0.33	0.10
Hypotype RR 4 (fig. 5, 6)	0.27	0.19	0.10

Locality: Hypotype RR 3 is from the Lundbreck section, sample 25, 168 feet above the base of the Bearpaw Formation.

Hypotype RR 4 is from the Castle River section, sample 1, near the upper end of the downstream exposure of the Bearpaw Formation.

Distribution: This species is very common throughout the Bearpaw Formation in the study area. A total of 3407 specimens were observed. It was originally described by Wickenden (1932, p. 86) from the Bearpaw Formation east of Manyberries, near Lethbridge, and near Lundbreck, Alberta.

Given and Wall (1971, p. 523) identified this species from the lower part of the Bearpaw Formation near Castor, Alberta.

Sliter (1968, p. 44) and Trujillo (1960, p. 305) reported *H. fraseri* from the Upper Campanian and Middle Turonian respectively in southern California.

Remarks: The majority of the specimens which have been assigned to this species by the writer are poorly preserved but are recognized by their transparency and loose coiling, which was noted by Wickenden (1932) in his original description. Also some of the specimens assigned to the undifferentiated *Haplophragmoides* category may also belong to this species. Specimen diameters ranged from 0.23 mm. to 0.75 mm.

HAPLOPHRAGMOIDES KIRKI Wickenden

Plate 1, figures 10-13

Haplophragmoides kirki Wickenden, 1932, Trans. Roy. Soc. Can., 3rd ser., vol. 26, sec. 4, p. 85-86, pl. 1, figs. 1a-c --- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 21-22, pl. 2, figs. 23a-c --- Wall, 1960, Res. Coun. Alberta Bull. 6, p. 18, pl. 3, figs. 11, 12; pl. 4, figs. 10, 11 --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 13, pl. 1, fig. 8 --- Sliter, 1968, Univ. Kans., Paleont. Contr., Art. 7, Protozoa, p. 44, pl. 2, figs. 2a, b --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 21-22, pl. 1, figs. 17a, b --- Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 523-524, pl. 1, figs. 5-8 --- Morris, 1971, Micropaleontology, vol. 17, no. 3, p. 267, pl. 2, fig. 10.

Haplophragmoides excavata Cushman and Waters forma *kirki*, Mello, 1971, U.S. Geol. Surv. Prof. Paper 393-C, p. C31-32, pl. 4, fig. 2.

Description: Test small, planispiral, close coiled; periphery broadly rounded, peripheral margin lobate; chambers distinct, involute, four or five chambers in final whorl; sutures distinct, radial, depressed; wall arenaceous, smooth, fine grained, with much cement, usually pyritized; aperture a low arch at base of last formed chamber; color grey in pyritized specimens, clear in non-pyritized specimens.

Dimensions:

	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype RR 5 (fig. 12, 13)	0.30	0.25	0.15
Hypotype RR 6 (fig. 10, 11)	0.32	0.29	0.17

Locality: The figured specimens are from Lundbreck, sample 68, 531 feet above the base of the Bearpaw Formation.

Distribution: This species is found throughout the Lundbreck section, especially in the upper two-thirds. *H. kirki* was also observed in samples collected from the Bearpaw Formation on the Oldman and Castle Rivers. 212 specimens were observed.

This species was originally described by Wickenden (1932) from the Bearpaw Shale east of Manyberries, Alberta. He also reported its occurrence at Lethbridge and Lundbreck. It appears to have its maximum development in the Bearpaw Formation, being reported by Given and Wall (1971, p. 524) near Castor, and by North and Caldwell (1970, p. 22) in Saskatchewan. Mello (1971, p. C31-32) reports this species from the Pierre Shale in Wyoming. Morris (1971, p. 267) found this species in the Campanian of northwestern Colorado.

H. kirki is also known from older Cretaceous rocks in western Canada, having been recorded in the Lea Park Formation of Saskatchewan (North and Caldwell, 1964, p. 13) and in the Puskwaskau Formation of northern Alberta (Wall, 1960, p. 18).

Sliter (1968, p. 44) reported this species in the Upper Campanian of southern California.

Remarks: This species is generally pyritized and is easily recognized. The size and shape are very close to Wickenden's types. A few specimens were observed that contained 5-6 chambers in the final whorl.

The non-pyritized specimens are flattened and closely resemble those of Mello (1971, pl. 4, fig. 2). Although thought by Mello to be a form of the species *H. excavata*, the species *H. kirki* is recognized by us as being valid. The diameter size varied from 0.15 to 0.48 mm.

HAPLOPHRAGMOIDES LINKI Nauss

Plate 1, figure 1, 2

Haplophragmoides linki Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 339, pl. 49, figs. 7a-b --- Morris, 1971, Micropaleontology, vol. 17, no. 3, p. 267-268, pl. 2, fig. 11.

? *Haplophragmoides* sp. cf. *H. linki* Nauss. Wall, 1960, Res. Coun. Alberta Bull. 6, p. 19, pl. 4, figs. 12-15.

Description: Test involute, planispiral, deeply umbilicate; periphery broadly rounded; chambers distinct, usually six in last whorl; sutures depressed, radial; wall arenaceous, fine grained, usually pyritized; aperture a low arched slit at base of apertural face, not usually visible; color usually dark bronze-grey.

Dimensions:

	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype RR 7 (fig. 1, 2)	0.35	0.32	0.12

Locality: The figured specimen is from Lundbreck, sample 13, 98 feet above the base of the Bearpaw Formation.

Distribution: This species was originally described from the base of Lloydminster Shale in east-central Alberta by Nauss (1947, p. 339).

H. linki is common throughout the Bearpaw Formation in the study area (892 specimens) and has also been observed in the Bearpaw Formation near Lethbridge by Anan-Yorke (1969, p. 44).

Wall (1960, p. 14) noted that this species occurs sporadically in the Kaskapau and Puskwaskau Shales of northern Alberta.

Morris (1971, p. 268) reports this species from the Campanian of northwestern Colorado.

Remarks: The majority of the specimens present are pyritized and are most easily recognized by the deep umbilication. Some specimens become partly evolute, especially the last one or two chambers. However, the specimens otherwise closely resemble Nauss' type.

The specimens varied from 0.20 mm. to 0.50 mm. diameter.

HAPLOPHRAGMOIDES sp. A

Plate 1, figure 14, 15

Description: Test involute, planispiral, periphery acute; chambers distinct, usually six in the last whorl; sutures flush to slightly limbate, straight to slightly curves; wall arenaceous, very

finely grained with much cement, giving an amorphous appearance; aperture a low slit at base of apertural face; color translucent white.

Dimensions:

	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Figured specimen RR 41 (fig. 14,15)	0.48	0.34	0.11

Locality: The figured specimen is from the Lundbreck section, sample 17, 124 feet above the base of the Bearpaw Formation.

Distribution: This species is rare in the samples and occurs only sporadically in the lower half of the section. Only 44 specimens were recovered.

Remarks: Although similar in some respects to *H. linki* Nauss, this form is not umbilicate and has thickened sutures. It may represent a form closely related to *H. linki* and perhaps is an ecologic variant of the latter.

HAPLOPHRAGMOIDES sp. B

Plate 1, figure 7-9

Description: Test evolute, planispiral, periphery rounded; chambers distinct, increasing gradually in size, eight in last whorl, later chambers slightly overlapping those of the previous whorl,

commonly three whorls in adult specimen; sutures distinct, radial to slightly sigmoid, depressed; wall fine to medium arenaceous, invariably pyritized; aperture not observed.

Dimensions:

	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Figured specimen RR 42 (fig. 7-9)	0.38	0.30	0.08

Locality: The figured specimen is from the Lundbreck section, sample 68, 531 feet above the base of the Bearpaw Formation.

Distribution: Only five specimens were found, four in sample 68 at Lundbreck, and one in sample 5 at the Castle River section.

Remarks: This form may have been referred to under the genus *Trochamminoides* in other papers. However, the chamber arrangement and development is too advanced to leave this form in the genus *Trochamminoides*. It has, therefore, been assigned to *Haplophragmoides*.

Family TROCHAMMINIDAE Schwager, 1877

Genus TROCHAMMINA Parker and Jones, 1859

TROCHAMMINA ALBERTENSIS Wickenden

Plate 1, figures 16-21

Trochammina albertensis Wickenden, 1932, Trans. Roy. Soc. Can., 3rd. Ser., vol. 26, sec. 4, p. 90, pl. 1, figs. 9a-c --- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 50, pl. 15, fig. 7 ---

Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 152, pl. 39, figs. 13, 14 --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 29-30, pl. 2, figs. 15a-c, 16a, b --- Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 526, pl. 1, figs. 9-11; pl. 3, figs. 1-3.

Description: Test trochoid, nearly circular in dorsal view, conical in peripheral view, deeply umbilicate; chambers distinct, arranged in three whorls with five chambers in the last whorl, chambers inflated, increasing gradually in size; sutures distinct, depressed, oblique; wall composed of fine grained arenaceous grains with much cement, smoothly finished, often pyritized; aperture a ventral arch opening on inner margin of last chamber; color yellow-white, brown when pyritized.

Dimensions:

	Diam. (mm.)	Thickness (mm.)
Hypotype RR 8 (fig. 16-18)	0.32	0.15
Hypotype RR 9 (fig. 19-21)	0.40	0.15

Locality: Hypotype RR 8 is from the Lundbreck section, sample 68, 531 feet above the base of the Bearpaw Formation.

Hypotype RR 9 is from the Castle River section, sample 1, near the top of the Bearpaw Formation.

Distribution: This species is one of the most common in the

study area, occurring throughout the entire Bearpaw Formation. The largest concentration of specimens is in the central portion of the section. 432 specimens were recovered.

Wickenden (1932, p. 90) described the holotype from the Bearpaw Formation near Lethbridge and also noted its presence in the Bearpaw Formation at Lundbreck.

Tappan (1962, p. 153) reported it from the Barrow Trail Member of the Schrader Bluff Formation, Alaska. North and Caldwell (1970, p. 29) reported finding this species throughout the Bearpaw Formation in southwestern Saskatchewan, especially in the Sherrard, Beechy, and Aquadell Members. Given and Wall (1971, p. 526) found *T. albertensis* in the lower part of the Bearpaw Formation in south-central Alberta. Anan-Yorke (1969, p. 56) confirms its occurrence in the Bearpaw Formation at Lethbridge.

Remarks: This species is present in three kinds of preservation. The most common preservation is as a brown, amorphous trochoid disc, with a darkened spire. The second kind is the pyritized form, such as hypotype RR 8. The third is the least altered, represented by hypotype RR 9. The aperture is only visible on the latter form. Generally specimens of this species are crushed upon fossilization unless pyritized. The diameter varied from 0.15 to 0.37 mm. in size.

Family ATAXOPHRAGMIIDAE Schwager, 1877

Genus VERNEUILINOIDES Loeblich and Tappan, 1949

VERNEUILINOIDES BEARPAWENSIS (Wickenden)

Plate 2, figures 8, 9

Verneuilina bearpawensis Wickenden, 1932, Trans. Roy. Soc. Can., 3rd. Ser., vol. 26, sec. 4, p. 87, pl. 1, fig. 8 --- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 31, pl. 7, figs. 4-6.

Verneuilinoides bearpawensis (Wickenden). Wall, 1960, Res. Coun. Alberta Bull. 6, p. 22-23, pl. 4, figs. 20-21 --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 75-76, pl. 4, figs. 31-34; pl. 5, figs. 13-15 --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 25, pl. 2, figs. 6a, b --- Given and Wall, 1971, Bull. Can. Pet. Geol. vol. 19, no. 2, p. 526, pl. 2, figs. 10-14.

? *Verneuilinoides* cf. *bearpawensis* (Wickenden). North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 15-16, pl. 2, figs. 3a, b.

Description: Test elongate, tapering, nearly circular in cross section, triserially spiralled with five convolutions; chambers distinct, inflated, increasing in size in each whorl; sutures distinct, curved, strongly depressed; wall composed of fine arenaceous material, much cement, smoothly finished, often pyritized; aperture a high arched opening on interior of last formed chamber; color generally brown.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype RR 10 (fig. 9)	0.53	0.20
Hypotype RR 11 (fig. 8)	0.52	0.20

Locality: Hypotype RR 10 is from the Lundbreck section, sample 68, 531 feet above the base of the Bearpaw Formation.

Hypotype RR 11 is also from the Lundbreck section, sample 57, 481 feet above the base of the Bearpaw Formation.

Distribution: *Verneuilinoides bearpawensis* is the most common and most abundant species in the study area, occurring throughout the entire Bearpaw Formation. It is present at the Lundbreck, Oldman River, and Castle River localities. 4458 specimens were recovered.

Wickenden (1932, p. 87) described the holotype from the Bearpaw Formation near Lethbridge.

North and Caldwell (1964, p. 15) reported *V.* sp. cf. *V. bearpawensis* from the upper part of the Lea Park Formation in Saskatchewan. They also recognized *V. bearpawensis* in the Bearpaw Formation of southwestern Saskatchewan (North and Caldwell, 1970, p. 25). Wall (1960, p. 22) recorded this species from the lower part of the Puskwaskau Formation along the lower Smoky River in the Plains region of northwestern Alberta. In the Foothills of central Alberta, Wall (1967, p. 75) indicated that the range of this species extends from the Opabin Member of the Blackstone Formation to the Nomad Member of the Wapiabi Formation (Turonian to Campanian). Given and Wall (1971,

p. 526) report it from the Bearpaw Formation in south-central Alberta. Anan-Yorke (1969, p. 61) noted that it was the most dominant species in the Bearpaw Formation at Lethbridge.

Remarks: This species is often crushed and flattened, losing most of its character. The pyritized specimens best display the features. Some specimens can be distinguished from crushed specimens of *Gaudryina bearpawensis* since the former lack the triangular triserial arrangement of chambers. The length varies from 0.25 to 0.75 mm.

Genus GAUDRYINA d'Orbigny, 1839

GAUDRYINA BEARPAWENSIS Wickenden

Plate 2, figures 1-4

Gaudryina bearpawensis Wickenden, 1932, Trans. Roy. Soc. Can., 3rd. Ser., vol. 26, sec. 4, p. 88, pl. 1, fig. 7 --- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 34, pl. 7, figs. 20, 21a-b, 22 --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 27, pl. 2, figs. 8, 10a-c, 11 --- Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 527, pl. 2, figs. 1-4.

Description: Test elongate, triserial in early stage, biserial in final stage, biserial portion twisted, tapering towards both ends but more towards the early portion; chambers distinct, globular, triserial portion with three rows of five to seven chambers each, triangular in cross section, biserial portion four to six chambers, sub circular in cross section; sutures distinct, depressed, slightly

curved; wall fine to medium grained, arenaceous, much cement, quite smoothly finished; aperture a broad semicircular arch at the base of interior face of the last chamber; color brownish-grey.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype RR 12 (fig. 3)	0.58	0.20
Hypotype RR 13 (fig. 1, 2)	0.56	0.20
Hypotype RR 14 (fig. 4)	0.29	0.14

Locality: All three hypotypes are from the Lundbreck section, sample 68, 531 feet above the base of the Bearpaw Formation.

Distribution: This species is very common in the upper two-thirds of the Bearpaw Formation at this locality. It also occurs in minor amounts in the lower part of the section. A total of 1213 specimens were observed.

The holotype was described by Wickenden (1932, p. 88) from the Bearpaw Formation near Lethbridge. He also noted its occurrence at Lundbreck.

This species is restricted to the Bearpaw Formation and has been found in Saskatchewan (North and Caldwell, 1970, p. 27), as well as in south-central Alberta (Given and Wall, 1971, p. 527).

Remarks: The specimens show a greater variation in form than those described by Wickenden. This variation is related to the stage

of development. The three hypotypes display three different stages of development. These are a juvenile or early triserial form, a mature or late triserial form, and a mature adult form which is both triserial and biserial. The biserial portion itself shows maturation development in many specimens, with two to six chambers present in the biserial stage, generally about five. The specimens differ from those described by Wickenden in being finer grained. The most common preservation is an unpyritized, crushed state in which characteristics are obscured. A variation in length from 0.25 to 0.77 mm. was recorded.

Genus DOROTHIA Plummer, 1931

DOROTHIA SP.

Plate 2, figures 10, 11

Dorothia sp., Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 527-528, pl. 2, fig. 5; pl. 3, figs. 4, 5.

Dorothia cf. *smokyensis* Wall, North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 28-29, pl. 2, figs. 13a, b.

Description: Test elongate, slightly twisted, early portion indistinct but probably three whorls with four chambers per whorl, later adult portion biserial, five pairs of interlocking chambers, chambers small, increasing rapidly in size in early portion, increasing gradually in size in adult portion, slightly inflated; sutures distinct only in adult portion, slightly curved and depressed in adult portion; wall finely arenaceous, much cement, invariably

pyritized, smoothly finished; aperture a high arched opening at base of interior face of last chamber; color brown.

Dimensions:

	Length (mm.)	Max. Width (mm.)
Figured specimen RR 43 (fig. 10,11)	0.54	0.15

Locality: The figured specimen is from the Castle River section, JW-RR-71-2, sample 4, near the middle of the Bearpaw Formation.

Distribution: This species is rare and is restricted to the mid-portion of the Bearpaw Formation in the Lundbreck and Castle River sections. Only 11 specimens were found.

Remarks: This species appears to be the same as that of Given and Wall (1971, p. 527-528) and North and Caldwell (1970, p. 28-29). Although very similar to *Dorothia smokyensis* Wall, this species lacks the well developed early portion and should not be placed in that species. It is, in all probability, an evolutionary derivative of *Dorothia smokyensis*. Its appearance throughout the Bearpaw Formation (Alberta and Saskatchewan) possibly warrants designation of a new species and the assignment of a new specific name.

Suborder MILIOLINA Delage and Herouard, 1896

Superfamily MILIOLACEA Ehrenberg, 1839

Family MILIOLIDAE Ehrenberg, 1839

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA SPHAERA Nauss

Plate 4, figures 21-23

Quinqueloculina sphaera Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 340, pl. 48, figs. 14a-c --- Tappan, U.S. Geol. Surv. Prof. Paper 236-C, p. 157, pl. 37, figs. 6a-c --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 17, pl. 3, figs. 1a-c --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 86, pl. 6, figs. 16-18 --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 30-31, pl. 3, figs. 1a-c --- Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 528, 530, pl. 3, figs. 10-12.

Description: Test small, subcircular in side view, inflated, periphery rounded; chambers arranged in quinqueloculine plan, four visible from one side, three from the other, alternate chambers increasing in diameter to an opposite end; sutures distinct, depressed; wall calcareous, porcellaneous, imperforate, surface smooth; aperture a slit at basal margin of the end of the last formed chamber; color amber or white.

Dimensions:

	Length (mm.)	Max. Diam. (mm.)	Min. Diam. (mm.)
Hypotype RR 15 (figs. 21-23)	0.27	0.20	0.15

Locality: Hypotype RR 15 is from the Lundbreck section, sample 68, 531 feet above the base of the Bearpaw Formation

Distribution: This species is rare (11 specimens) in the present study, occurring only sporadically in the upper 500 feet of the Bearpaw Formation.

Recorded from both the Wapiabi and Lea Park Formations, it is quite common and is used as a guide fossil in the middle Lea Park Formation in Saskatchewan (North and Caldwell, 1964). It is one of the forms which reinhabited the Cretaceous sea of the western interior during the deposition of the Bearpaw Formation, being recorded in Saskatchewan by North and Caldwell (1970, p. 31) from the Snakebite and Aquadell Members, in south-central Alberta by Given and Wall (1971, p. 530), and near Lethbridge by Anan-Yorke (1969, p. 67).

Remarks: The specimens are more oval than Nauss' type, but the chamber arrangement and the aperture are similar enough to retain it in *Q. sphaera* Nauss.

Suborder ROTALIINA Delage and Herouard, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Family NODOSARIIDAE Ehrenberg, 1838

Genus DENTALINA Risso, 1826

DENTALINA BASIPLANATA Cushman, 1938

Plate 3, figures 10, 11

Dentalina basiplanata Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 68, pl. 24, figs. 1-6 --- Frizzell, 1954, Texas Bur. Econ.

Geol. Rept. Invest. 22, p. 86, pl. 9, figs. 32-33 - Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 174, pl. 45, fig. 17 --- Graham and Church, 1963, Stanford Univ. Pub., vol. VIII, no. 1, p. 27-28, pl. 2, fig. 11 --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 32-33, pl. 3 (synonomy) --- Mello, 1971, U.S. Geol. Surv. Prof. Paper 393-C, p. 22, pl. 2, fig. 8.

Description: Test elongate, uniserial, slightly arched; up to eight chambers, slightly compressed in early part (first four chambers) except for globular proloculus, unornamented, chambers in later part becoming globular and increasing gradually in size as added; sutures distinct, straight to moderately oblique, especially in earlier portion, flush to slightly limbate in earlier portion, usually depressed in later portion; wall calcareous, smooth; aperture terminal, radiate, produced at the end of a short neck on the concave side of the last formed chamber.

Dimensions:

	Length (mm.)	Max. Width (mm.)
Hypotype RR 16 (fig. 10)	1.30	0.25
Hypotype RR 17 (fig. 11)	1.26	0.30

Locality: Hypotype RR 16 is from the Lundbreck section, sample 55, 468 feet above the base of the Bearpaw Formation.

Hypotype RR 17 is from the Lundbreck section, sample 86, 753 feet above the base.

Distribution: This species is not common (30 specimens) and is restricted to the upper half of the Bearpaw Formation in the study area. It is however a very common world-wide Upper Cretaceous species (North and Caldwell, 1970, p. 32). Cushman (1946, p. 68) reported it from the beds of Navarro and Taylor ages in the Gulf Coastal Plain. It has been reported from the Lea Park Formation (lower Campanian) in south-central Saskatchewan (North and Caldwell, 1964, p. 18), and from the Bearpaw Formation in southwestern Saskatchewan (North and Caldwell, 1970, p. 33). Anan-Yorke (1969, p. 72) reported it from the Bearpaw Formation at Lethbridge. Mello (1971, p. 23) reported it from the Pierre Shale in Wyoming, and Tappan (1962, p. 174) from the Schrader Bluff Formation of Santonian and Campanian age in northern Alaska.

Remarks: The specimens are usually fragmentary and show considerable variation. Mello (1971, p. 23) notes that "species of the genus *Dentalina* are often quite variable in their morphology, and in view of the fact that there have been no attempts at detailed quantification of variability for most species, variants of *D. basiplanata* may have been recorded in Canada, Alaska, and the western interior under different specific names.". Originally some specimens were thought to belong to *D. legumen* Ruess, but the variation associated with *D. basiplanata,* especially in the obliquity of the sutures and the development of the proloculus, led us to place all specimens in *D. basiplanata*.

Superfamily BULIMINACEA Jones, 1875

Family TURRILINIDAE Cushman, 1927

Genus NEOBULIMINA Cushman and Wickenden, 1928

NEOBULIMINA CANADENSIS Cushman and Wickenden

Plate 4, figures 5, 6

Neobulimina canadensis Cushman and Wickenden, 1928, Cushman Lab. Foram. Research Contr., vol. 4, p. 13, pl. 1, figs. 1-2 --- Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 125, pl. 52, figs. 11, 12 --- Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 340, pl. 48, figs. 5a-b --- Frizzell, 1954, Bur. Econ. Geol. Rept. Invest. 22, p. 116, pl. 17, fig. 11 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 185, pl. 48, figs. 18-27 --- Mello, 1969, U.S. Geol. Surv. Prof. Paper 611, p. 97-80, pl. 9, figs. 4, 5 --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 42, pl. 3, figs. 18a-b --- Mello, 1971, U.S. Geol. Surv. Prof. Paper 393-C, p. 37-38, pl. 6, fig. 1 --- Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 532-534, pl. 4, figs. 1-4.

Praebulimina venusae (Nauss). North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 21, pl. 3, figs. 13a-b.

Description: Test elongate, tapering, early portion triserial, twisted, obscure, about three whorls comprising 1/4 to 1/2 of the length of the test; later portion biserial, three to four whorls; chambers in triserial portion small, slightly inflated, usually about nine chambers; chambers in biserial portion more inflated, subglobular,

about six chambers; sutures distinct, curved, depressed; wall calcareous, smooth; aperture loop-shaped, on inner face of last chamber; color white to grey in unpyritized specimens.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype RR 18 (var. *beta*)(fig. 6)	0.22	0.10
Hypotype RR 19 (var. *alpha*)(fig. 5)	0.20	0.12

Locality: The hypotypes are from the Lundbreck section, sample 73, 553 feet above the base of the Bearpaw Formation.

Distribution: This species is present only in the upper half of the section and was found only at the Lundbreck locality. Its occurrence is sporadic but quite common in the upper half of the section, where it is invariably associated with *Praebulimina venusae*. A total of 164 specimens were recovered.

This species was originally described from the Bearpaw Shale near Lethbridge. Since then it has been recognized extensively in the Upper Cretaceous of North America. It has been found throughout the Bearpaw Formation in Canada and also in the Pierre Shales in the western interior, as well as in the Schrader Bluff Formation in Alaska (Tappan, 1962, p. 185).

Remarks: Mello (1969, p. 79) noted two varieties *alpha* and *beta* in the species. Most of the specimens in the present study belong to

the variety *beta*, which is inconsistent with the Bearpaw specimens of Given and Wall (1971, p. 534). The variety *beta* (hypotype RR 18) has a much reduced triserial portion and an elongate biserial portion. The var. *alpha* (hypotype RR 19) generally has a smaller length/width ratio and appears more robust than var. *beta*. The size of the specimens is less than those of Mello. The size range is from 0.15 to 0.28 mm. in length.

Genus PRAEBULIMINA Hofker, 1953

PRAEBULIMINA VENUSAE (Nauss)

Plate 4, figures 7, 8

Bulimina venusae Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 334-335, pl. 48, fig. 10.

Praebulimina venusae (Nauss). Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 188, pl. 49, figs. 19-21 --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 94, pl. 15, figs. 19-22 --- Sliter, 1968, Univ. Kansas, Paleont. Contr., Art. 7, Protozoa, p. 86, pl. 12, figs. 5a, b --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 42, pl. 3, figs. 15a, b; 16a, b --- Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 534-535, pl. 4, figs. 5, 6 --- Morris, 1971, Micropaleontology, vol. 17, no. 3, p. 278, pl. 6, fig. 7.

Description: Test small, tapering towards both ends, especially toward the proximal end, triserial, usually four to five whorls, triangular in cross section; chambers of earlier whorls low, chambers

of last two whorls inflated and increasing rapidly in size; sutures distinct, depressed; wall calcareous, smooth; aperture a comma-shaped opening on the inner face of the last formed chamber; color yellow to brown.

Dimensions:

	Length (mm.)	Max. Width (mm.)
Hypotype RR 20 (fig. 8)	0.36	0.20
Hypotype RR 21 (fig. 7)	0.28	0.14

Locality: Hypotype RR 20 is from the Lundbreck section, sample 98, 790 feet above the base of the Bearpaw Formation.

Hypotype RR 21 is also from the Lundbreck section, sample 68, 531 feet above the base.

Distribution: This species occurs commonly in the middle portion of the section, with only rare occurrences in the lower portion, and minor occurrences in the upper portion. This species was also found in one sample from the lower part of the Bearpaw Formation at the Castle River locality. A total of 206 specimens were observed.

This species lived through most of Senonian time over much of North America. Originally described from Lea Park beds near Vermilion, Alberta (Nauss, 1947, p. 334-335), it has since been recorded from middle and late Campanian rocks in the Foothills of Alberta (Wall, 1967, p. 94), Coniacian to Campanian age rocks in Alaska (Tappan, 1962, p. 188), and late Campanian beds in southern California (Sliter,

1968, p. 86). It has been recorded in the Bearpaw Formation of Saskatchewan by North and Caldwell (1970, p. 42), and in Alberta by Given and Wall (1971, p. 534), where they found it typical of the lower part of the Bearpaw Formation. Anan-Yorke (1969, p. 80-81) found this species in the lower part of the Bearpaw Formation near Lethbridge, Alberta.

Remarks: This species is often associated with *Neobulimina canadensis*, *Serovaina orbicella*, and to some extent, *Gavelinella talaria*. However, it is sometimes present in samples which are almost exclusively arenaceous. A size range from 0.15 to 0.27 mm. in length was recorded.

Superfamily DISCORBACEA Ehrenberg, 1838

Family DISCORBIDAE Ehrenberg, 1838

Genus EOEPONIDELLA Wickenden, 1949

EOEPONIDELLA LINKI Wickenden

Plate 4, figures 9-14

Eoeponidella linki Wickenden, 1949, Trans. Roy. Soc. Can., 3rd ser., vol. 42 (1948), sec. 4, p. 81-82, text fig. 1 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 195, pl. 54, figs. 9-10 --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 44, pl. 4, figs. 1a-c; 2a-c.

? *Eoeponidella* cf. *E. linki* Wickenden. Wall, 1967, Res. Coun. Alberta Bull. 20, p. 98, pl. 15, figs. 34-39.

Description: Test small, planoconvex, spiral side convex, umbilical side concave, five chambers in final whorl, only chambers of final whorl visible on umbilical side, with small supplementary chambers covering their inner margin around the umbilicus; sutures distinct, oblique and flush on the spiral side, straight and depressed on the umbilical side; wall calcareous, finely perforate, smooth; aperture a small interiomarginal arch, rarely visible.

Dimensions:

	Diam. (mm.)	Thickness (mm.)
Hypotype RR 22 (fig. 9-11)	0.20	0.10
Hypotype RR 23 (fig. 12-19)	0.20	0.11

Locality: The hypotypes are both from the Lundbreck section, hypotype RR 22 from sample 73, 553 feet above the base of the Bearpaw Formation, and hypotype RR 23 from sample 68, 531 feet above the base.

Distribution: This species is not common (31 specimens) and is restricted to the middle portion of the Bearpaw Formation in this locality.

Originally described from the Lea Park in Saskatchewan, this species is time restricted (middle and late Campanian) and occurs elsewhere only in the Sentinel Hill Member of the Schrader Bluff Formation of Alaska (Tappan, 1962, p. 195), and in the Sherrard and Beechy Members of the Bearpaw Formation in Saskatchewan (North and Caldwell, 1970, p. 44). Anan-Yorke recorded this species in the Bearpaw

Formation near Lethbridge. As well, Wall (1967, p. 98-99) recorded a species closely similar to *E. linki* from the Nomad Member of the Wapiabi Formation in the Rocky Mountain Foothills of Alberta.

Remarks: This species closely resembles *E. strombodes* Tappan. The stellar arrangement of supplementary chambers is also present in *E. linki*, and this is not a criterion for distinguishing between these two species. However, the supplementary chambers extend more than half of the distance towards the periphery in *E. strombodes*. As well, *E. strombodes* has seven chambers in the final whorl, whereas *E. linki* only has five. Preservation is usually poor and some pyritization is often present.

EOEPONIDELLA STROMBODES Tappan

Plate 4, figures 15-20

Eoeponidella strombodes Tappan, 1951, Cushman Found. Foram. Res., Contr., vol. 2, pt. 1, p. 6, pl. 1, figs. 22a-c --- Tappan, 1951, *in* Payne and others, U.S. Geol. Surv. Oil and Gas Invest. Map OM-126, sheet 3, fig. 21(4a-c) --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 195-196, pl. 54, figs. 5-8 --- Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 535, pl. 3, figs. 8, 9; pl. 5, figs. 19-21.

Description: Test free, small biconvex to planoconvex, trochospiral, periphery subacute; all whorls visible on spiral side, only final whorl visible on umbilical side with supplementary chambers

extending slightly more than half way to the periphery, usually seven chambers in final whorl, all about the same size; sutures distinct, slightly oblique and flush on spiral side, straight and depressed on umbilical side; wall calcareous, finely perforate, smooth; aperture an umbilical arch on final chamber, adjacent to preceding stellate chamber, rarely visible; color yellow-brown.

Dimensions:

	Diam. (mm.)	Thickness (mm.)
Hypotype RR 24 (fig. 18-20)	0.25	0.15
Hypotype RR 25 (fig. 15-17)	0.20	0.06

Locality: The hypotypes are both from the Lundbreck section, sample 27, 178 feet above the base of the Bearpaw Formation.

Distribution: This species occurs only in the sample from which the hypotypes were taken, and a total of three specimens were recovered. There were no other specimens observed in the Bearpaw Formation in the study area.

Tappan (1962, p. 195) reports it from the Sentinel Hill Member of the Schrader Bluff Formation in Alaska. Bergquist's work (1966, p. 145) indicates that it is restricted to the lower 400 feet of that same member. Given and Wall (1971, p. 535) report it as a common component in the middle and upper shale units of the Bearpaw Formation near Castor, Alberta.

Remarks: The preservation is rather poor, but the alternation of primary and secondary chambers can be observed on hypotype RR 25. In *E. linki*, the secondary chambers are more parallel to the adjacent primary chambers. The present specimens seem to be less biconvex than those reported by Tappan (1962, p. 145), but otherwise bear a very close resemblance.

Genus SEROVAINA Sliter, 1968

SEROVAINA ORBICELLA (Bandy)

Plate 3, figures 1-9

Gyroidina globosa (Hagenow) var. *orbicella* Bandy, 1951, Jour. Paleont., vol. 25, no. 4, p. 505, pl. 74, figs. 2a-c --- Morris, 1971, Micropaleontology, vol. 17, no. 3, p. 279, pl. 7, figs. 7-8.

Serovaina orbicella (Bandy). Sliter, 1968, Univ. Kansas Paleont. Contr., Art. 7, Protozoa, p. 92, pl. 13, figs. 12a-c (synonomy) --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 46, pl. 6, figs. 2, 3 --- Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 535-536, fl. 4, figs. 10-18.

Description: Test free, trochospiral, spiral side slightly convex, evolute, all chambers visible, umbilical side strongly convex, involute, small umbilicus, periphery rounded; chambers inflated, increasing rapidly in size, usually seven in final whorl; wall calcareous, finely perforate, wall smooth; sutures distinct, radial, depressed; aperture low interiomarginal slit at base of last formed chamber, extending from the spiral side of the periphery into the umbilicus, occasionally with a small lip; color amber.

Dimensions:

	Diam. (mm.)	Thickness (mm.)
Hypotype RR 26 (fig. 4-6)	0.37	0.20
Hypotype RR 27 (fig. 7-9)	0.33	0.18
Hypotype RR 28 (fig. 1-3)	0.28	0.16

Locality: All hypotypes are from the Lundbreck section. Hypotype RR 26 is from sample 98, and hypotypes RR 27 and 28 are from sample 68, the samples being 790 and 531 feet above the base of the Bearpaw Formation respectively.

Distribution: *Serovaina orbicella* is the most common and long ranging calcareous foraminifera in the Bearpaw Formation of the study area. A total of 1199 specimens were recovered.

Originally described from Campanian and Maestrichtian beds in California and adjacent parts of Mexico (Bandy, 1951; Sliter, 1968), its extension into Canada was recorded by North and Caldwell (1964) in the Lea Park Formation of south-central Saskatchewan. North and Caldwell (1970) further recorded its existence in the Bearpaw Formation of Saskatchewan. Given and Wall (1971) extended its distribution into the Bearpaw Formation of Alberta.

Remarks: The specimens present display a better developed apertural lip than those described by Sliter (1968). This seems to be characteristic of Bearpaw specimens (Given and Wall, 1971; North and Caldwell, 1970). Also, on some specimens the aperture extends along

the periphery and reaches the spiral side of the peripheral margin. The size range is very large, with specimens from 0.13 mm. to 0.60 mm. in diameter observed.

Superfamily SPIRILLINACEA Reuss, 1862

Family SPIRILLINIDAE Reuss, 1862

Genus SPIRILLINA Ehrenberg, 1843

SPIRILLINA? sp.

Plate 3, figures 21, 22

Description: Test discoidal, planispiral, six coils around a small proloculum, coiling regular with slight tube diameter increase in outer whorls; spiral suture distinct, depressed; wall calcareous, perforate, smooth, sometimes pyritized; aperture not observed.

Dimensions:

	Diam. (mm.)	Thickness (mm.)
Figured specimen RR 44 (fig. 21)	0.15	0.02
Figured specimen RR 45 (fig. 22)	0.27	0.04

Locality: Figured specimens RR 44 and RR 45 are both from the Lundbreck section, sample 73, 553 feet above the base of the Bearpaw Formation, and sample 55, 468 feet above the base, respectively.

Distribution: Only seven specimens in a total of three samples were recovered, all from the middle portion of the section, from 468

to 557 feet above the base.

Specimens referred to the genus *Spirillina* have also been recorded near the base of the Bearpaw Formation at Lethbridge by Anan-Yorke (1969, p. 88).

Remarks: Although preservation is too poor to allow observation of the pores, the specimens are thought to belong to the genus *Spirillina*.

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862

Family HETEROHELICIDAE Cushman, 1927

Genus HETEROHELIX Ehrenberg, 1843

HETEROHELIX GLOBULOSA (Ehrenberg)

Plate 4, figures 1-4

Gümbelina globulosa (Ehrenberg). Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 105-106, pl. 45, figs. 9-15 (synonymy) --- Stelck and Wall, 1954, Res. Coun. Alberta Rept. 68, p. 22, pl. 2, figs. 20a-b --- Frizzell, 1954, Texas Bur. Econ. Geol. Rept. Invest. 22, p. 109, pl. 15, figs. 24-27.

Heterohelix globulosa (Ehrenberg). Gallitelli, 1957, U.S. Nat. Mus. Bull. 215, p. 137, pl. 31, figs. 12-15 --- Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 196, pl. 55, figs. 1, 2 --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 21, pl. 3, figs. 11a-b --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 102, pl. 3, figs. 26-37 --- Sliter, 1968, Univ. Kansas Contr. Paleont., Art. 7, Protozoa, p. 94-95, pl. 14, figs. 1-3 ---

Mello, 1969, U.S. Geol. Surv. Prof. Paper 611, p. 70-71, pl. 8, figs. 5a, b --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 47-49, pl. 4, figs. 6a, b (synonomy) --- Mello, 1971, U.S. Geol. Surv. Prof. Paper 393-C, p. 35, pl. 5, fig. 8 --- Given and Wall, 1971, Bull Can. Pet. Geol., vol. 19, no. 2, p. 536, pl. 5, figs. 22-25 --- Morris, 1971, Micropaleontology, vol. 17, no. 3, p. 280, pl. 7, fig. 3.

Description: Test small, gently flaring from initial blunt end, biserial, peripheral outline indented; chambers distinct, increasing rapidly in size and becoming increasingly inflated as added, later chambers nearly globular, five pairs of chambers present; sutures distinct, depressed, slightly curved; wall calcareous, hyaline, finely perforate, smoothly finished; aperture an arched opening at inner margin of last chamber; colorless to yellow.

Dimensions:

	Length (mm.)	Width (mm.)	Thickness (mm.)
Hypotype RR 29 (fig. 1, 2)	0.24	0.16	0.09
Hypotype RR 30 (fig. 3, 4)	0.18	0.13	0.08

Locality: The hypotypes are both from the Lundbreck section, sample 53, 455 feet above the base of the Bearpaw Formation.

Distribution: Only nine specimens were found, restricted to the interval 411 to 468 feet above the base of the Bearpaw Formation.

This species, as redefined by Pessagno (1967, p. 260), ranges throughout strata of Campanian and Maestrichtian ages.

In western Canada, it has been reported from the Kaskapau Formation in the Plains region of northwestern Alberta (Stelck and Wall, 1954, p. 22). Wall (1960, p. 29; 1967, p. 104) noted it from the Puskwaskau Shale and the Vimy Member of the Blackstone Formation respectively. Given and Wall (1971, p. 536) recognized it in the Bearpaw Formation of south-central Alberta, and Anan-Yorke (1969, p. 90-91) recognized it in the Bearpaw Formation near Lethbridge. North and Caldwell (1970, p. 47-49) recorded it from the Bearpaw Formation of southwestern Saskatchewan, as well as in the Lea Park Formation of central Saskatchewan (North and Caldwell, 1964, p. 21). Tappan (1962, p. 196) recorded this species from the Seabee Formation in Alaska. Cushman (1946, p. 106) recorded this species in both the Navarro and Taylor Groups of the Gulf Coast area in the southern United States.

Remarks: The specimens are too poorly preserved to show a good aperture or any surface ornamentation which might have been present. Mello (1971, p. 35) notes faint striations on some individuals of this species from the Pierre Shale in Wyoming.

Family GAVELINELLIDAE Brotzen, 1956

Genus GAVELINELLA Brotzen, 1942

GAVELINELLA TALARIA (Nauss)

Plate 3, figures 12-20

Anomalina talaria Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 334, pl. 48, figs. 11, 12.

Anomalinoides talaria (Nauss). Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 200, pl. 58, figs. 6-10 --- North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 24, pl. 4, figs. 10a-c --- Wall, 1967, Res. Coun. Alberta Bull. 20, p. 112-114, pl. 6, figs. 10-15; pl. 9, figs. 25-27; pl. 15, figs. 7-12.

Gavelinella talaria (Nuuss). Kent, 1967, Jour. Paleont., vol. 41, no. 6, p. 1453-1454, pl. 184, figs. 10a-c --- North and Caldwell, 1970, Saskatchewan Res. Coun. Rept. 9, p. 54, pl. 6, figs. 4, 5 --- Given and Wall, 1971, Bull. Can. Pet. Geol., vol. 19, no. 2, p. 538, pl. 5, figs. 1-6 --- Morris, 1971, Micropaleontology, vol. 17, no. 3, p. 282, pl. 7, fig. 10.

Description: Test nearly biconvex, umbilical side partly evolute, especially later chambers, spiral side involute, periphery rounded; chambers distinct, usually nine in last whorl; sutures distinct, depressed, curved, sometimes slightly limbate; wall calcareous, hyaline, finely perforate; aperture an arched slit on the peripheral margin of last chamber, extending onto the ventral side along the umbilical edge of the last four or five chambers.

Dimensions:

	Max. Diam. (mm.)	Thickness (mm.)
Hypotype RR 31 (fig. 15-17)	0.28	0.12
Hypotype RR 32 (fig. 12-14)	0.26	0.08
Hypotype RR 33 (fig. 18-20)	0.20	0.07

Locality: Hypotypes RR 31, 32 and 33 are all from the Lundbreck section, samples 50, 68, and 100; 435, 531 and 801 feet above the base of the Bearpaw Formation respectively.

Distribution: This species is very common in the Lundbreck section above 400 feet above the base and is also present in the sections on the Castle and Oldman Rivers. A total of 1261 specimens were observed.

The species was originally described from the Lea Park beds in east-central Alberta by Nauss (1947, p. 334). It has since been reported in the Lea Park Formation in Saskatchewan by North and Caldwell (1964, p. 24). Wall (1967, p. 112-114) recognized it in the Wapiabi Formation of the Alberta Foothills, as did Tappan (1962, p. 200) in the Schrader Bluff Formation of Alaska. North and Caldwell (1970, p. 54) and Given and Wall (1971, p. 538) recognized this species in the Bearpaw Formation in southwestern Saskatchewan and south-central Alberta respectively. It is regarded as a Coniacian-early Maestrichtian fossil.

Remarks: The specimens are generally slightly smaller than the types of Nauss, however a size range from 0.08 to 0.40 mm. diameter is present. Some specimens approach a plano-convex form, resembling *G. sandidgei* (Brotzen), rather than the typical biconvex form of *G. talaria* (Nauss). However, frequently the specimens appear to be crushed and flattened, thus explaining the changes in shape. The specimens closely resembled *G. talaria* when checked with Nauss' type. Specimens ranging in diameter from 0.10 mm. to 0.40 mm. were observed.

Order OCULOSIDA Haeckel, 1887

Suborder NASSELLINA Ehrenberg, 1875

Division CYRTELLARI Haeckel, 1882

Superfamily ARCHIPILIICAE Haeckel, 1882

Subsuperfamily TRIACARTILAE Campbell, 1954

Family STICHOCORYTHIDAE Haeckel, 1882

Subfamily STICHOCORYTHINAE Haeckel, 1882

Genus DICTYOMITRA Haeckel, 1887

DICTYOMITRA MULTICOSTATA Zittel, 1876

Plate 4, figure 28

Dictyomitra multicostata Zittel. Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 341, pl. 48, fig. 3.

Description: Body conical, prominent longitudinal ribs, consisting of seven joints with six deep strictures, length and width of joints gradually increasing.

Dimensions:

	Length (mm.)	Width (mm.)
Hypotype RR 48 (fig. 28)	0.23	0.10

Locality: Hypotype RR 48 is from the Lundbreck section, sample 73, 553 feet above the base of the Bearpaw Formation.

Distribution: The hypotype was the only specimen recorded in the Bearpaw Formation in the study area.

It has been recorded elsewhere in the Bearpaw Formation by Given (1969, p. 120) near Castor.

Nauss (1947, p. 341) recorded it from the Lea Park Shale in east-central Alberta.

Remarks: The specimen is incomplete and pyritized.

Class DIATOMACEAE Agardh, 1824

Type A

Plate 4, figures 26, 27

Type A. Given and Wall, 1971, Bull. Can. Pet. Geol., v. 19, no. 2, p. 540, 541, pl. 3, figs. 16-19.

Description: Valve circular, surface gently convex, girdle narrow. Valve invariably pyritized.

Dimensions:

	Diam. (mm.)	Thickness (mm.)
Figured specimen RR 47 (figs. 26, 27)	0.18	0.05

Locality: The figured specimen is from the Castle River, sample 7, near the base of the Bearpaw Formation.

Distribution: Only one specimen was recovered from near the middle of the Bearpaw Formation at Lundbreck. Fifteen specimens were recovered from near the base of the Bearpaw Formation on the Castle River (sample 7).

Given and Wall (1971, p. 541) report Type A from the Bearpaw Formation near Castor and also report its occurrence in older Cretaceous rocks in Western Canada.

Type B

Plate 4, figures 24, 25

Type B. Given and Wall, 1971, Bull. Can. Pet. Geol., v. 19, no. 2, p. 541, pl. 3, figs. 20, 21.

Description: Valve circular, surface gently convex, girdle wide. Valve invariably pyritized.

Dimensions:

	Diam. (mm.)	Thickness (mm.)
Figured specimen RR 48 (figs. 24, 25)	0.20	0.10

Locality: The figured specimen is from Lundbreck, sample 90, 765 feet above the base of the Bearpaw Formation.

Distribution: Eight specimens were found in three samples from Lundbreck, ranging throughout the section, and five specimens in one sample were recovered from the lower part of the Bearpaw Formation on the Castle River.

Given and Wall (1971, p. 541) report this type from the Bearpaw Formation at Castor and report its occurrence in older Cretaceous beds in Alberta.

Phylum ARTHROPODA

Class CRUSTACEA

Subclass OSTRACODA Latreille, 1806

Order PODOCOPIDA Muller, 1894

Suborder PODOCOPINA Sars, 1866

Superfamily CYPRIDACEA Baird, 1845

Family CYPRIDIDAE Baird, 1845

Subfamily CANDONINAE Daday, 1900

Genus RECONCAVONA Krommelbein, 1962

RECONCAVONA sp. A

Plate 5, figures 16, 17

Description: Elongate shell, subelliptical, compressed; dorsum arched, venter slightly concave; ends rounded, greatest height anteromedial, LV larger than RV; surface rather smooth except for

anterior and posterior nodes as well as dorsal and ventral nodal development.

Dimensions:

	Length (mm.)	Height (mm.)
Figured specimen RR 49 (fig. 16)	0.78	0.44
Figured specimen RR 50 (fig. 17)	1.05	0.62

Locality: The figured specimens are both from the Waterton River locality, JW-RR-71-3, sample 3, 30 feet above the base of the Bearpaw Formation.

Distribution: This species was found only in this one sample and is restricted to the fresh to brackish water portion of the Bearpaw Formation.

Remarks: Although Krommelbein (1962) does not figure a species of *Reconcavona* which is as nodose as the present species, the specimens are placed in this genus because of the similarity in the shape of the valves and the overlap. This species may belong in the genus *Candona*.

RECONCAVONA sp. B

Plate 5, figure 15

Description: Shell elliptical, compressed; dorsum nearly straight, venter slightly concave; ends broadly rounded, greatest height postmedian, LV larger than RV; surface with fine pits.

Dimensions:

	Length (mm.)	Height (mm.)
Figured specimen RR 51 (fig. 15)	0.78	0.48

Locality: The figured specimen is from the Waterton River section, sample 3, 30 feet above the base of the Bearpaw Formation.

Distribution: This species is restricted to the lower fresh to brackish water part of the Bearpaw Formation in the study area.

Remarks: This species is quite similar to *Reconcavona unicinata* Krommelbein (1962, p. 487). It differs from *R.* sp. A since it is not nodose.

Family ILYOCYPRIDIDAE Kaufman, 1900

Subfamily CYPRIDEINAE Martin, 1940

Genus CYPRIDEA Bosquet, 1852

CYPRIDEA sp. A

Plate 5, figure 13

Description: Shell subquadrate, moderately convex; dorsum slightly convex, venter slightly sinuate; LV larger than RV; slight anteroventral notch with small beak; surface pitted.

Dimensions:

	Length (mm.)	Height (mm.)
Figured specimen RR 52 (fig. 13)	0.95	0.60

Locality: The figured specimen is from the Waterton River locality, sample 4, 40 feet above the base of the Bearpaw Formation.

Distribution: This species is restricted to the fresh to brackish water part of the Bearpaw Formation and was observed in only one sample.

Remarks: The specimen has been crushed badly during preservation, causing the dorsal margin to be less straight than is characteristic of the genus. However, a definite anteroventral notch is present, and the species is put in the genus *Cypridea*.

CYPRIDEA sp. B

Plate 5, figure 14

Description: Shell subquadrate, compressed; dorsum slightly arched, venter slightly sinuate; LV larger than RV with considerable overlap; small anteroventral notch with projecting beak; surface finely pitted.

Dimensions:

	Length (mm.)	Height (mm.)
Figured specimen RR 53 (fig. 14)	1.07	0.58

Locality: The figured specimen is from the Waterton River locality, sample 4, 40 feet above the base of the Bearpaw Formation.

Distribution: This species was only found in one sample and is restricted to the lower fresh to brackish water part of the Bearpaw Formation.

Remarks: This species is different from *Cypridea* sp. A in that the beak is larger, the overlap is greater, and the valves are more compressed in *C.* sp. B.

Family PONTOCYPRIDIDAE Muller, 1894

Genus PONTOCYPRIS Sars

PONTOCYPRIS sp.

Plate 5, figure 12

Description: Shell elongate, subtriangular, thickest anteromedial; dorsum arched, venter straight; posterior end strongly extended and pointed, anterior end rounded; surface smooth.

Dimensions:

	Length (mm.)	Height (mm.)
Figured specimen RR 54 (fig. 12)	0.45	0.27

Locality: The figured specimen is from the Waterton River, sample 4, 40 feet above the base of the Bearpaw Formation.

Distribution: This species was only found in the one sample. It is restricted to the fresh to brackish water part of the Bearpaw Formation.

Remarks: Only free valves are present and they are poorly preserved. It is difficult to determine the overlap and the valves would appear to be nearly equal in size.

Superfamily CYTHERACEA Baird, 1850

Family CYTHERIDEIDAE Sars, 1925

Subfamily CYTHERIDEINAE Sars, 1925

Genus HAPLOCYTHERIDEA Stephenson, 1936

HAPLOCYTHERIDEA sp. A

Plate 5, figures 1, 2

Description: Shell subtriangular, greatest height anteromedial; dorsum arched, venter straight; anterior rounded, posterior tapering, blunt; LV larger than RV; surface pitted.

Dimensions:

	Length (mm.)	Width (mm.)	Height (mm.)
Figured specimen RR 55 (figs. 1,2)	0.58	0.30	0.38

Locality: The figured specimen is from the Lundbreck section, sample 13, 98 feet above the base of the Bearpaw Formation.

Distribution: This species was the lowest occurring marine species observed in the Bearpaw Formation in the study area. It occurs from 98 to 790 feet above the base of the Bearpaw Formation at Lundbreck.

Remarks: The shape of the specimen in a lateral view resembles *Cytheridea*, but when viewed dorsally the ends are pointed and therefore this species belongs to the genus *Haplocytheridea*.

HAPLOCYTHERIDEA sp. B

Plate 5, figures 3, 4

Description: Shell subtriangular, greatest height anteromedial; dorsum arched, venter straight; anterior rounded, posterior tapering and acute; LV larger than RV; surface pitted with small anteroventral spines.

Dimensions:

	Length (mm.)	Width (mm.)	Height (mm.)
Figured specimen RR 56 (figs. 3,4)	0.88	0.42	0.51

Locality: The figured specimen is from the Lundbreck section, sample 27, 178 feet above the base of the Bearpaw Formation.

Distribution: This species was found only in the sample from which the figured specimen was taken.

Remarks: This species differs from *Haplocytheridea* sp. A in that *H.* sp. B has a pointed posterior and anteroventral spines.

HAPLOCYTHERIDEA sp. C

Plate 5, figure 11

Description: Shell subovate, greatest height anteromedial, compressed; dorsum arched, venter straight; anterior rounded, posterior tapering, rounded; LV larger than RV with good overlap; surface pitted.

Dimensions:

	Length (mm.)	Height (mm.)
Figured specimen RR 57 (fig. 11)	1.12	0.63

Locality: The figured specimen is from the Lundbreck section, sample 47, 411 feet above the base of the Bearpaw Formation.

Distribution: This species is found in the lower and central portions of the Lundbreck section from 178 to 540 feet above the base of the Bearpaw Formation. It was also found near the base of the Bearpaw Formation on the Castle River.

Remarks: This species differs from the other two species of *Haplocytheridea* described herein in that it is often compressed and has a larger length/width ratio. It lacks any anteroventral spines.

Family TRACHLEBERIDIDAE Sylvester-Bradley, 1948

Genus VEENIA Butler and Jones, 1957

VEENIA sp. A

Plate 5, figures 5-8

Description: Shell subquadrate to ovate, inflated; dorsum and venter nearly straight; posterior and anterior rounded; three subparallel ridges, median ridge slightly curved, anteromarginal ridge extending from dorsal to ventral ridges; surface pitted.

Dimensions:

	Length (mm.)	Width (mm.)	Height (mm.)
Figured specimen RR 58 (figs. 5,6)	0.80	0.52	0.45
Figured specimen RR 49 (figs. 7,8)	0.83	0.52	0.38

Locality: The figured specimens are from the Lundbreck section, sample 27, 178 feet above the base of the Bearpaw Formation.

Distribution: This species is present in the lower and middle portions of the section, from 98 to 468 feet above the base of the Bearpaw Formation.

Remarks: The well developed anteromarginal ridge and pitted surface distinguish this species from *Veenia* sp. B.

VEENIA sp. B

Plate 5, figures 9, 10

Description: Shell subquadrate, inflated; dorsum and venter nearly straight; posterior and anterior rounded; three subparallel ridges, median ridge slightly diagonal to length and slightly curved, slight anteromarginal ridge; reticulate surface.

Dimensions:

	Length (mm.)	Width (mm.)	Height (mm.)
Figured specimen RR 60 (figs. 9, 10)	0.90	0.32	0.49

Locality: The figured specimen is from the Lundbreck section, sample 55, 468 feet above the base of the Bearpaw Formation.

Distribution: This species occurs in the central and upper portions of the Lundbreck section, from 455 to 790 feet above the base of the Bearpaw Formation. This species was also found at the Castle River and Oldman River localities.

Remarks: The three longitudinal ribs and the reticulate ornamentation are the characteristic features of this species.

Khan (1970) figures *Veenia ornatoreticulata* Butler and Jones from the Miocene of Ghana which is quite similar to the present *V.* sp. B.

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EXPLANATION OF PLATES 1, 1A

Figs. 1, 2. *Haplophragmoides linki* Nauss, Lundbreck, X 85;

1, 2. Hypotype RR 7, side and peripheral-apertural views....67

Figs. 3-6. *Haplophragmoides fraseri* Wickenden, Lundbreck, Castle River, X 85;

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5, 6. Hypotype RR 4, side and peripheral-apertural views......63

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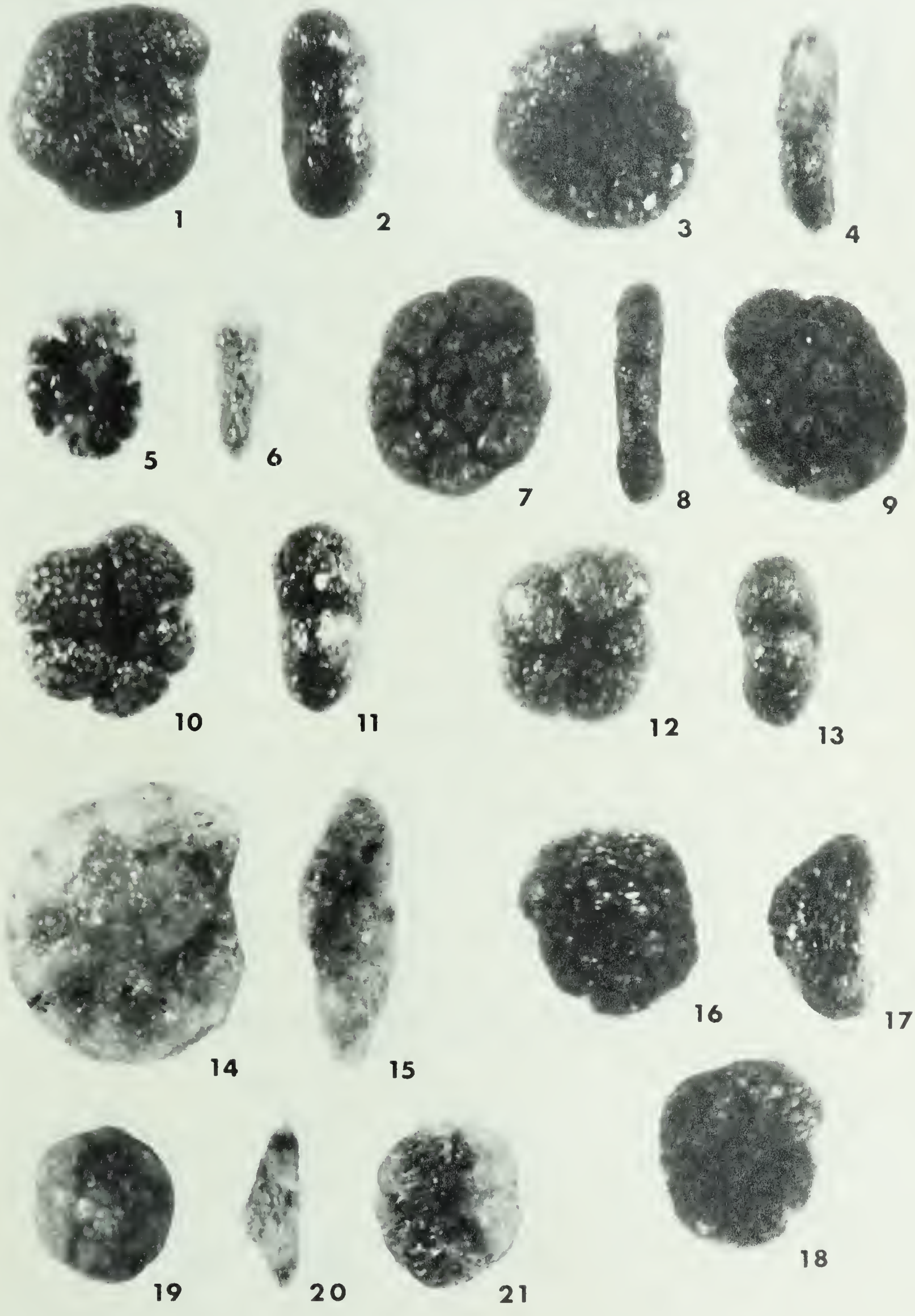

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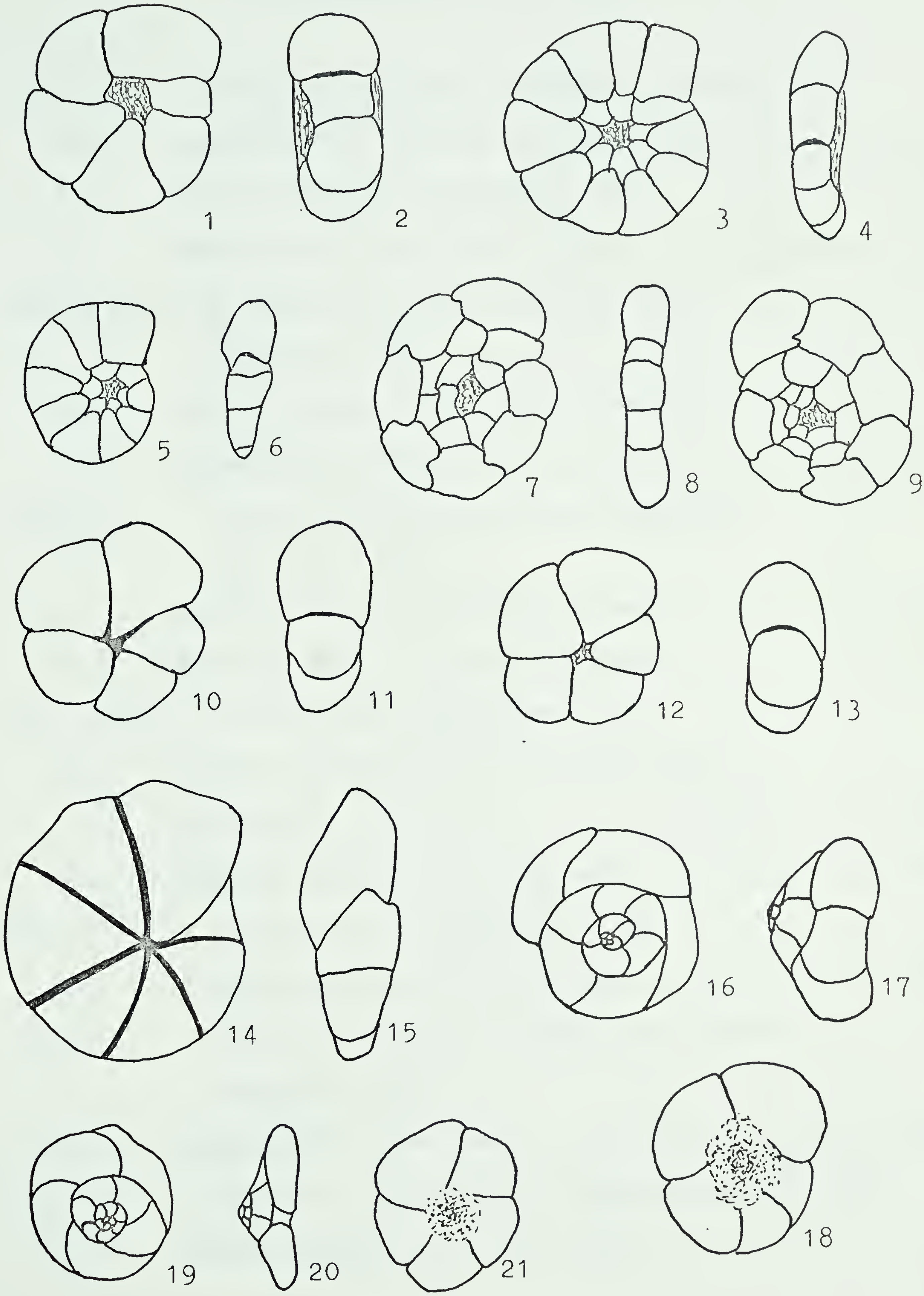

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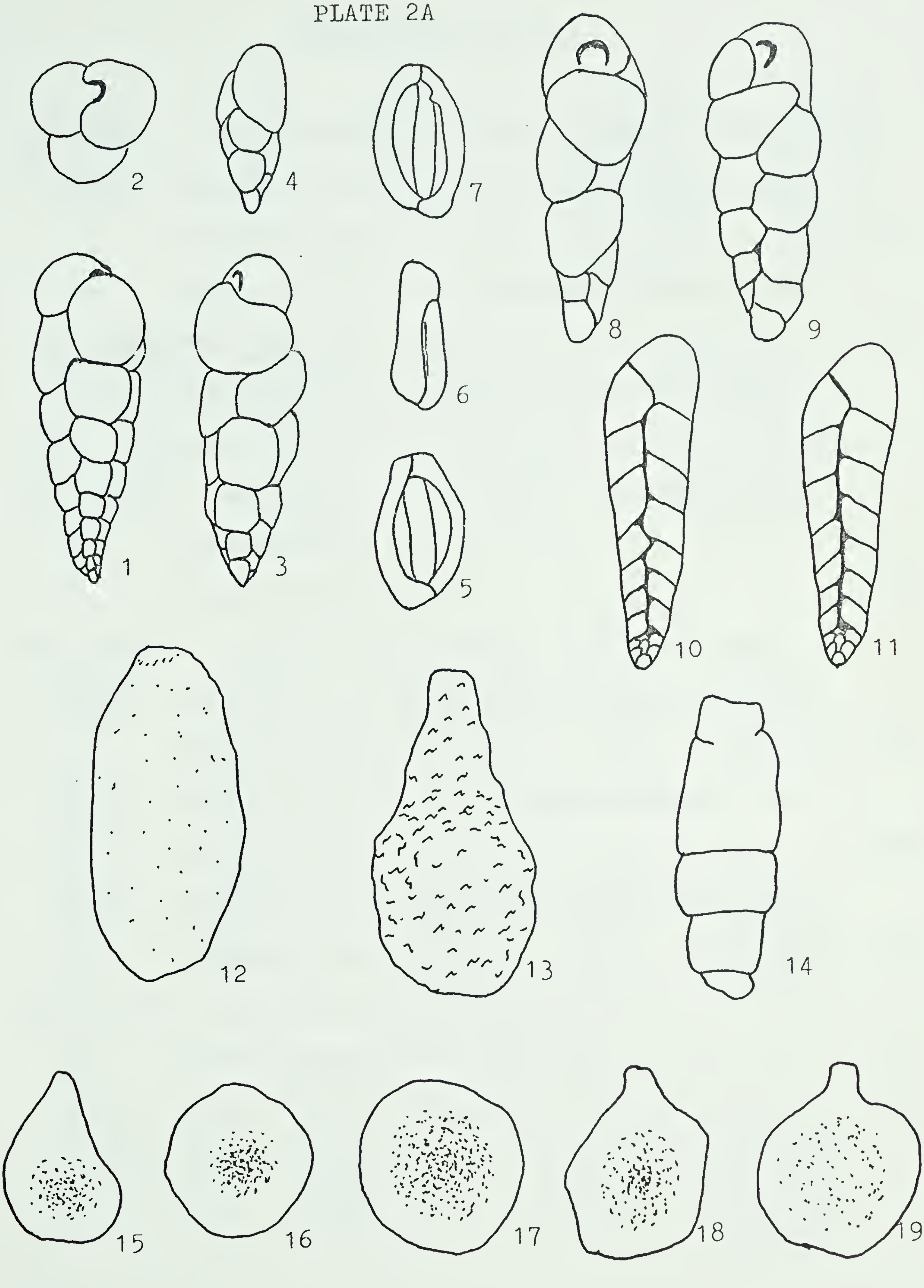
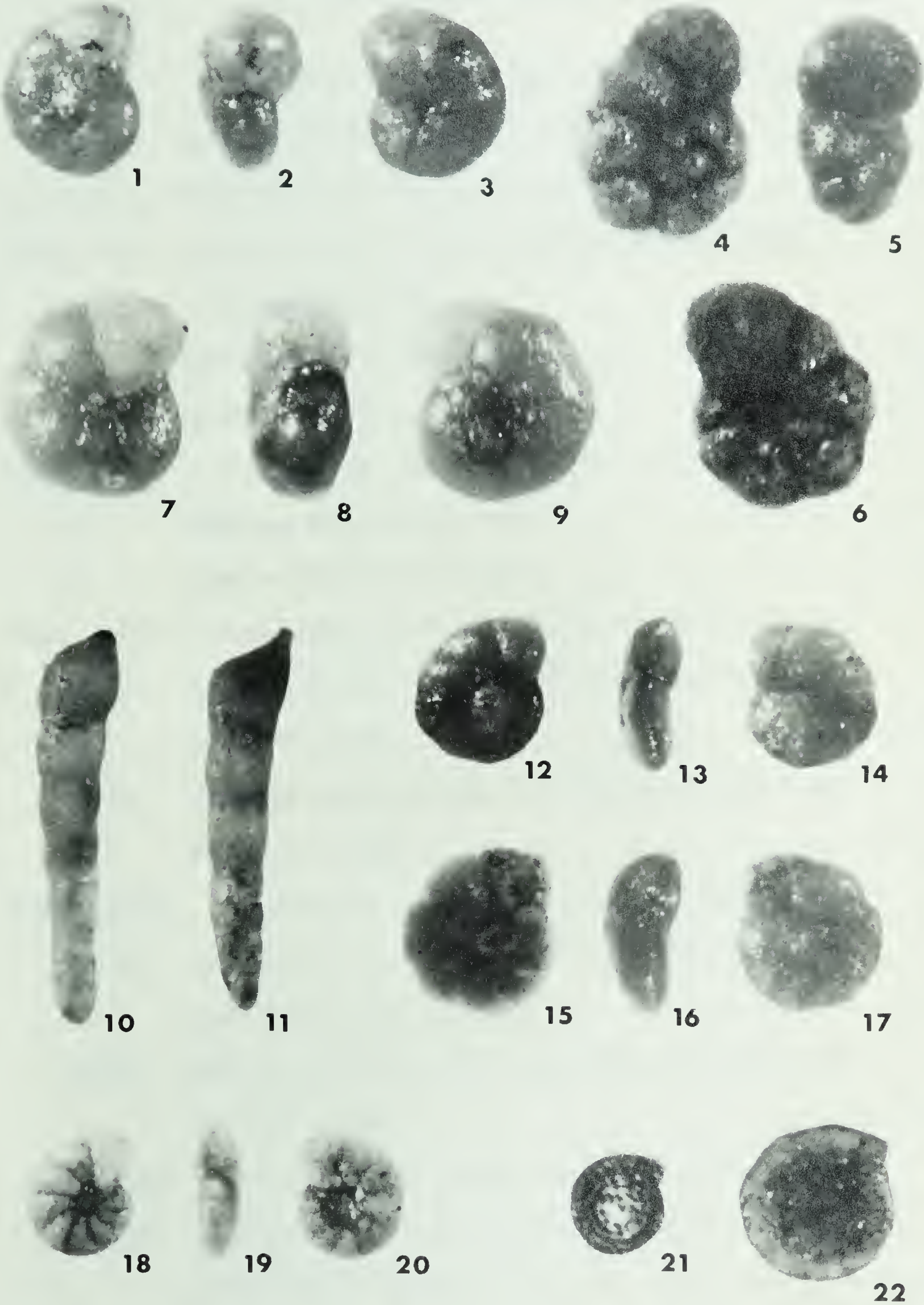


EXPLANATION OF PLATE 3

PLATE 3



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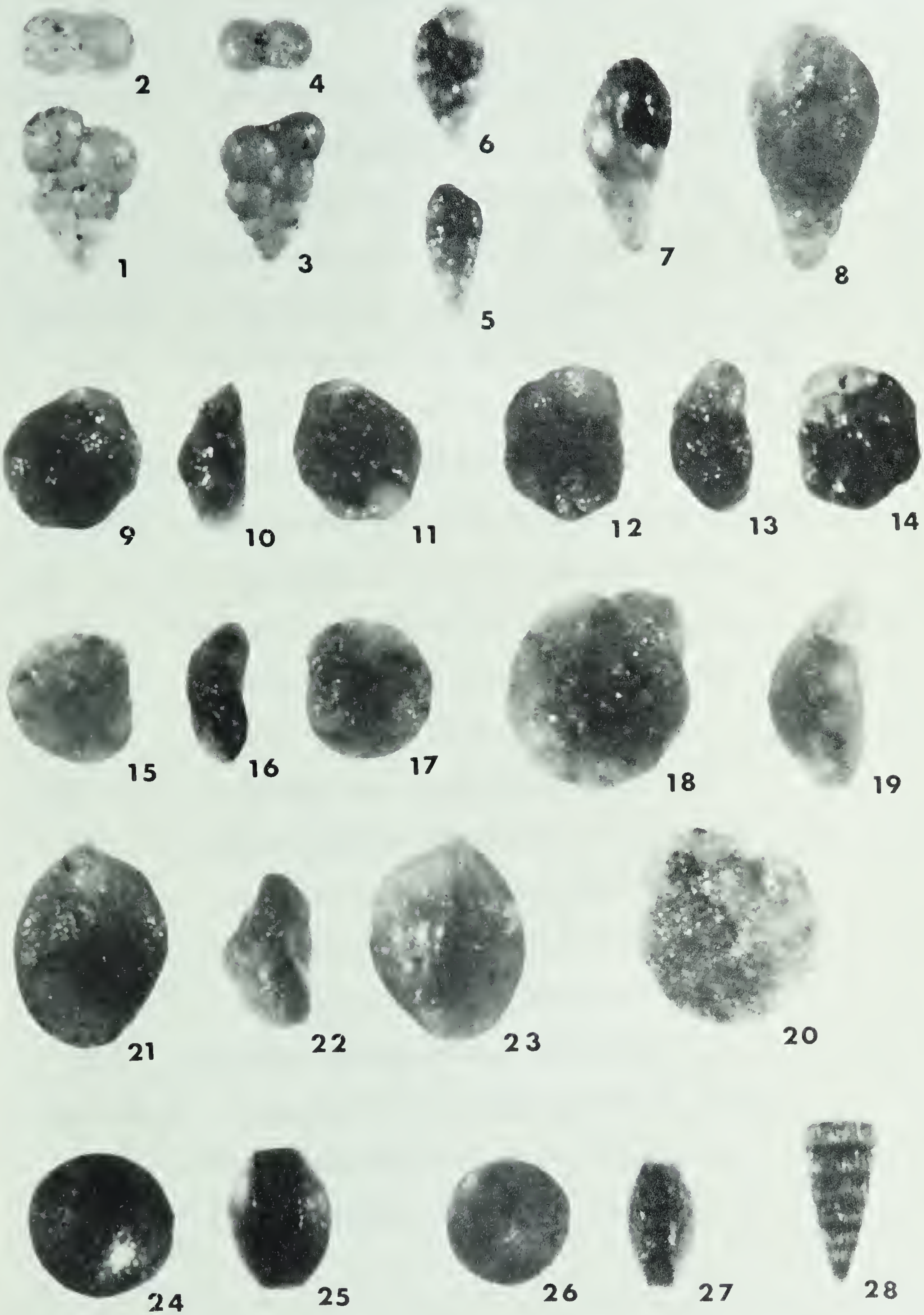

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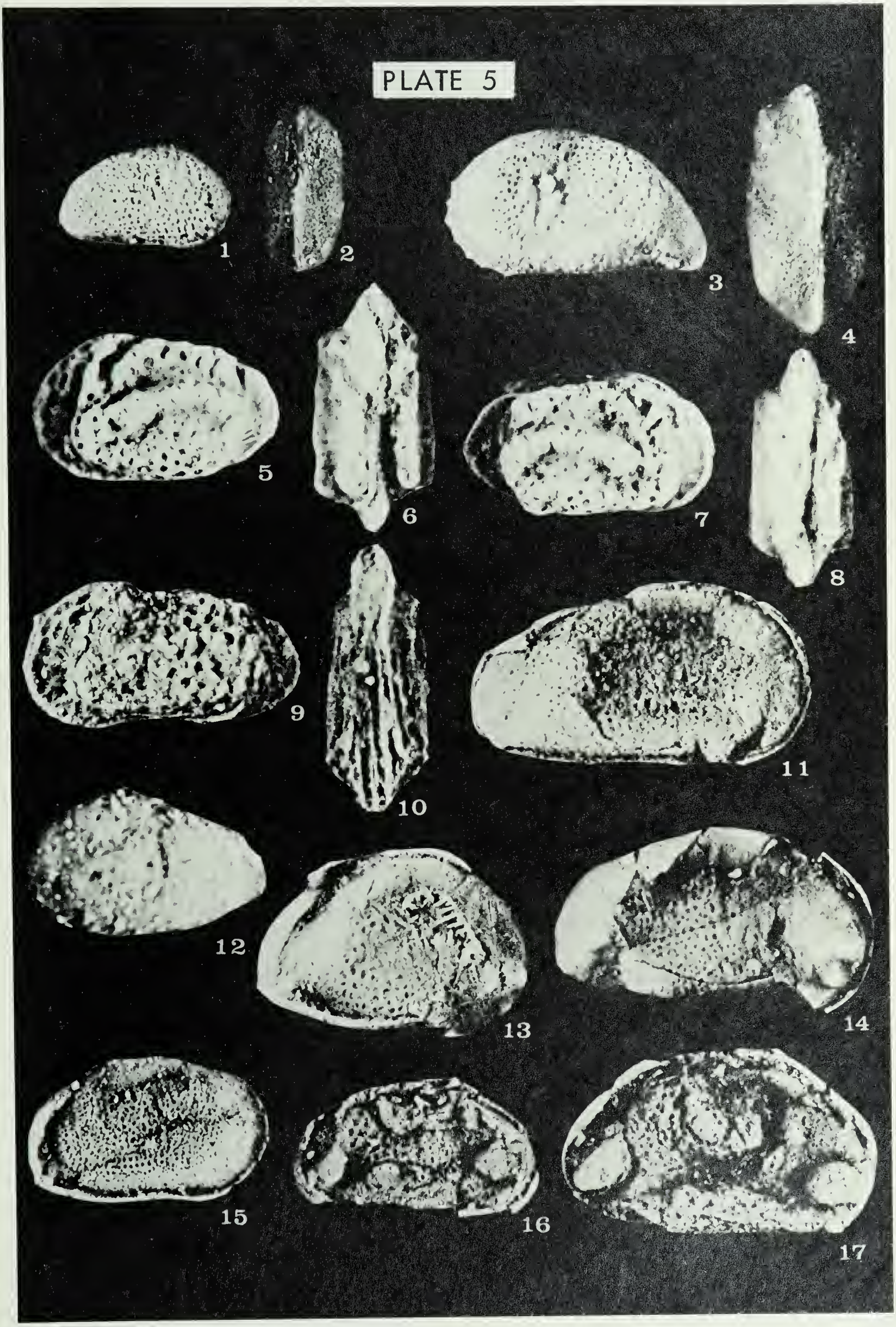
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